Jet-medium coupling in heavy ion collisions

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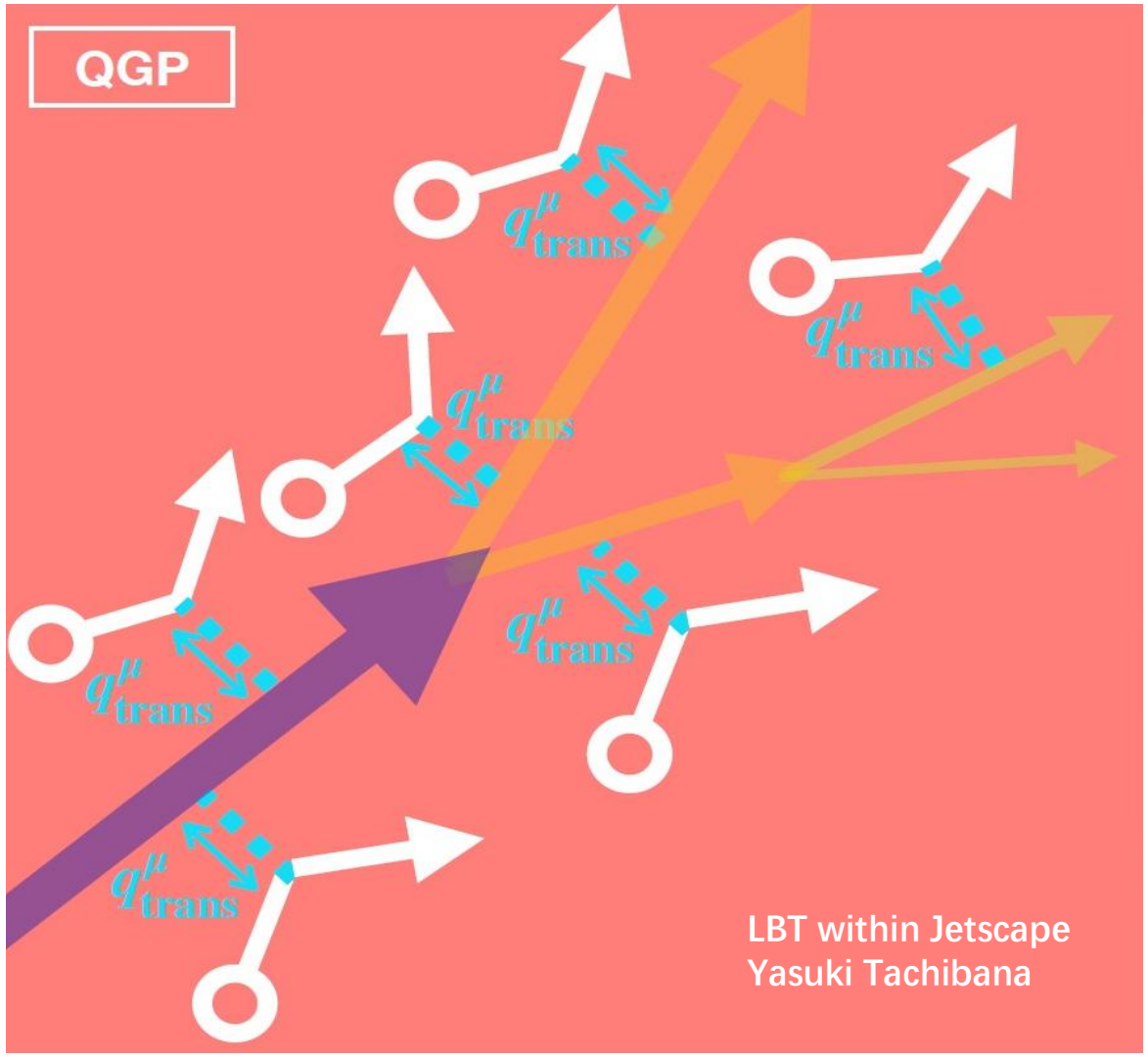
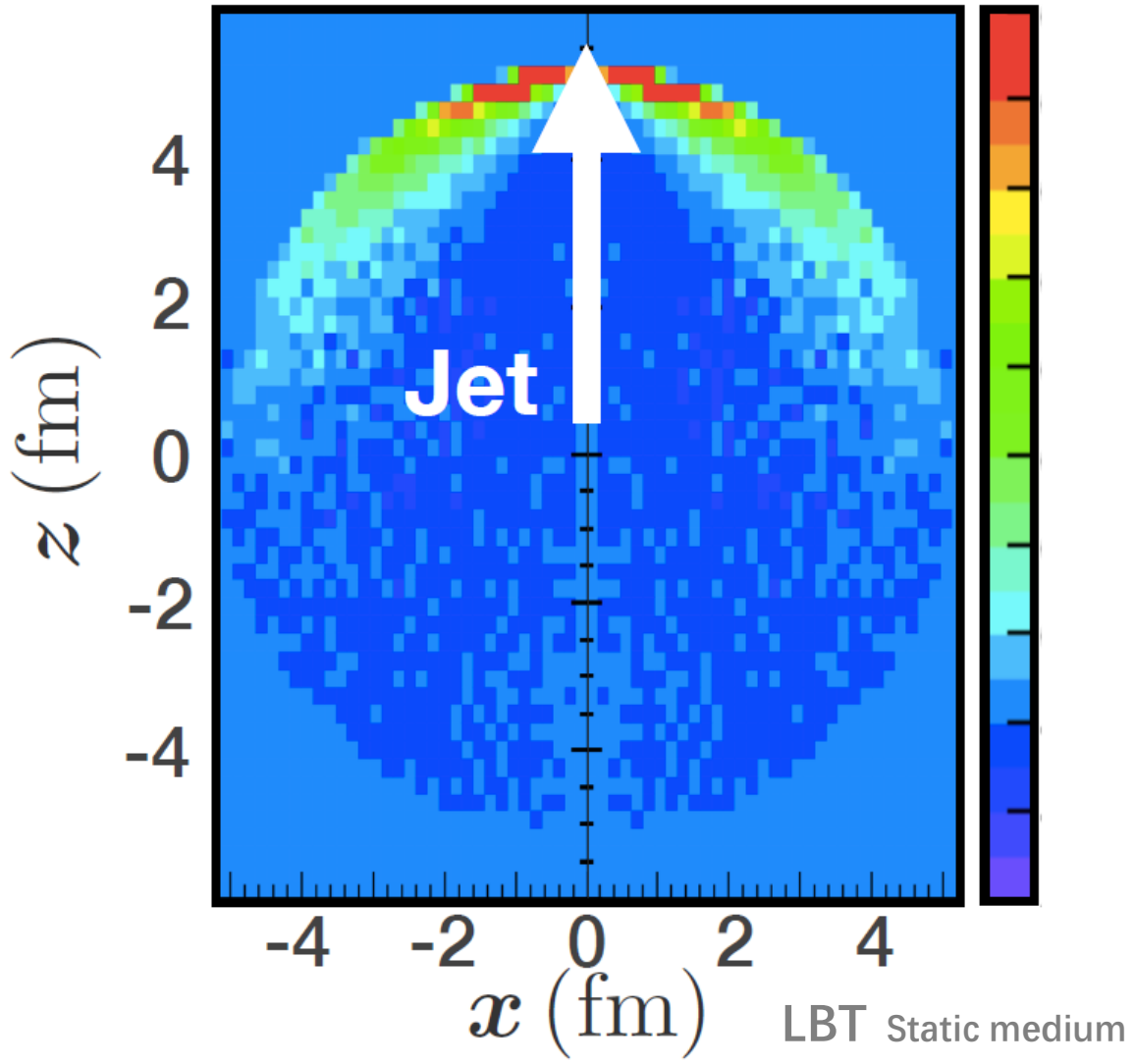
In collaboration with Yayun He, Carlos A. Salgado, Xin-Nian Wang

Jet induced medium response

Negative particle, Particle hole,
Wake, Initial thermal parton



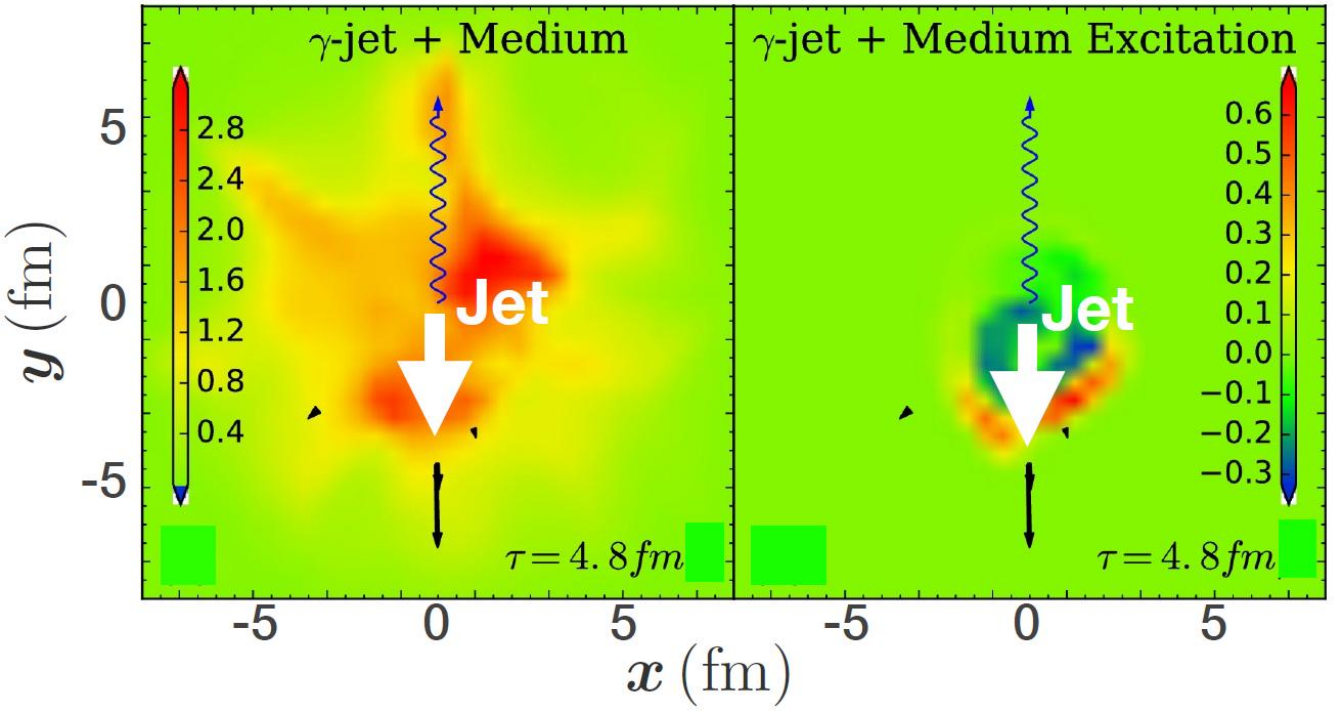
Energy-momentum conservation



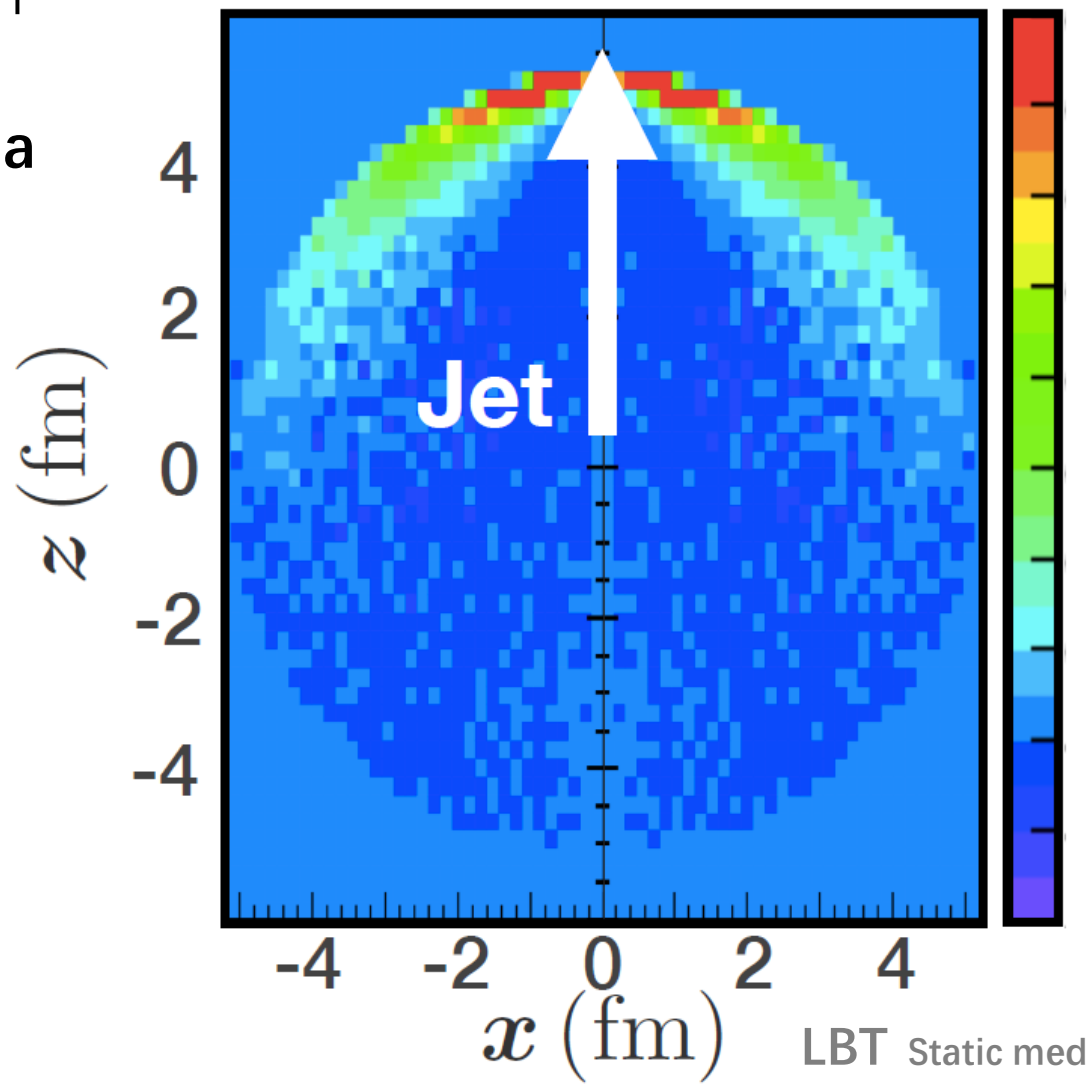
Jet induced medium response

- **Structure of medium response**
  Jet induced mach cone followed by a diffusion wake.
- **Distorted due to jet-medium interaction in a flowing medium**

CoLBT-hydro Phys.Lett. B777 86-90



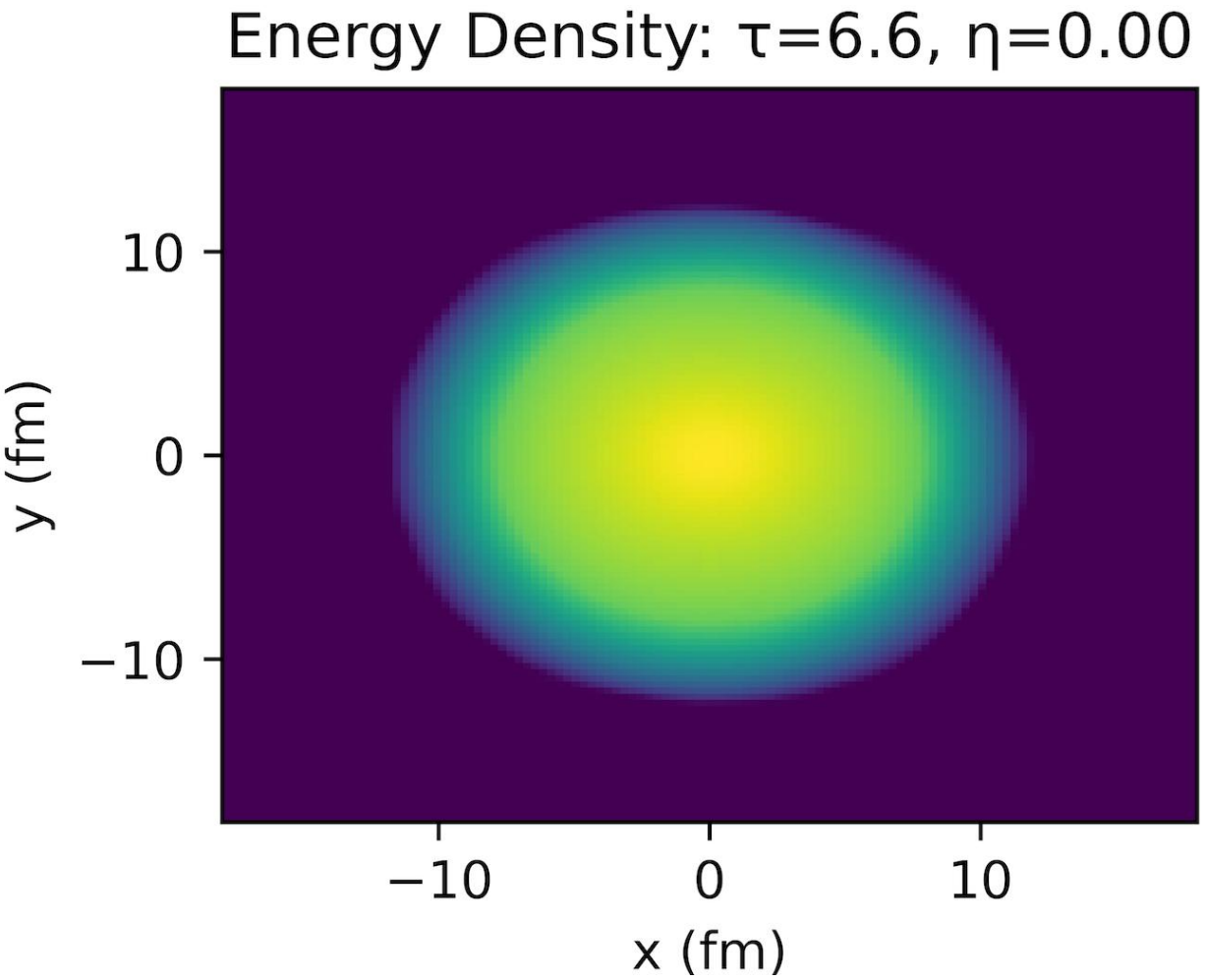
Energy-momentum conservation

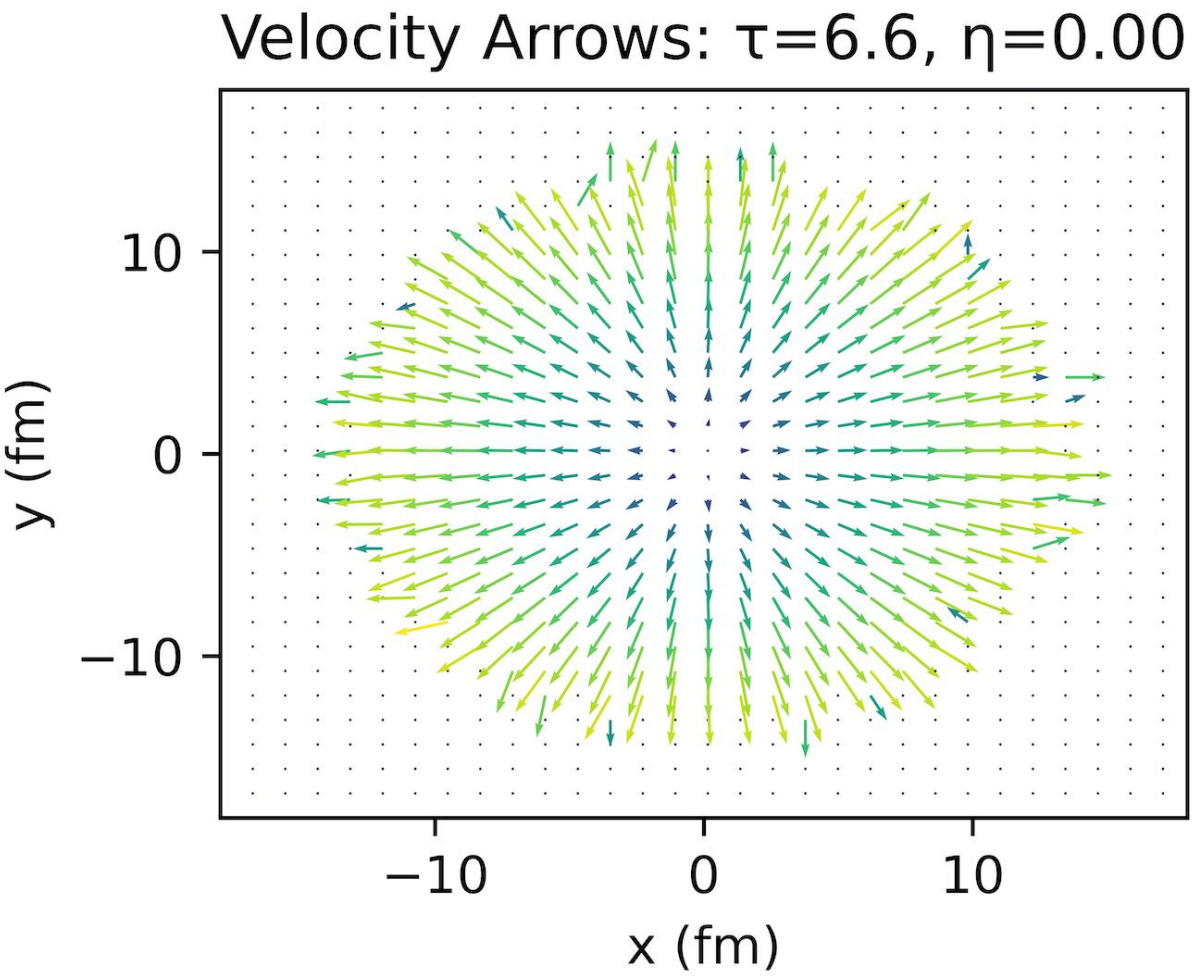


LBT Static medium

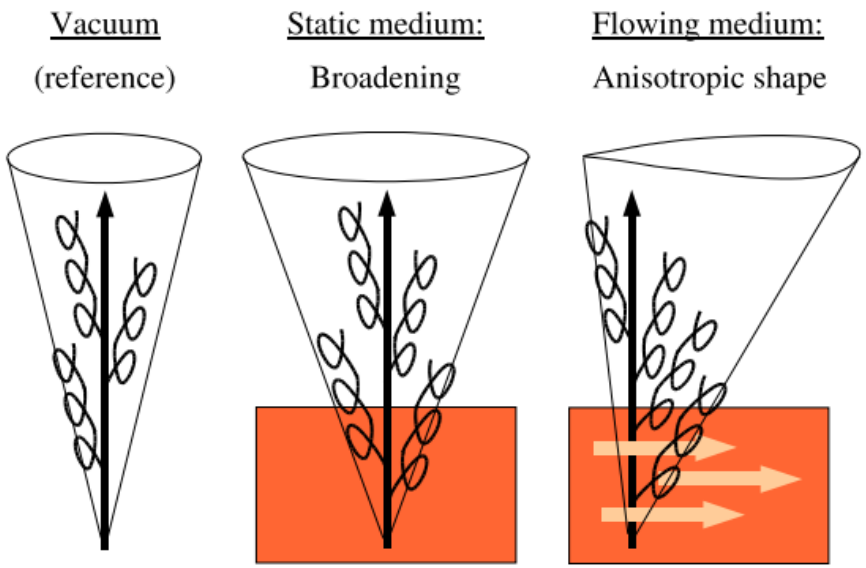
Jet-flow coupling in QGP

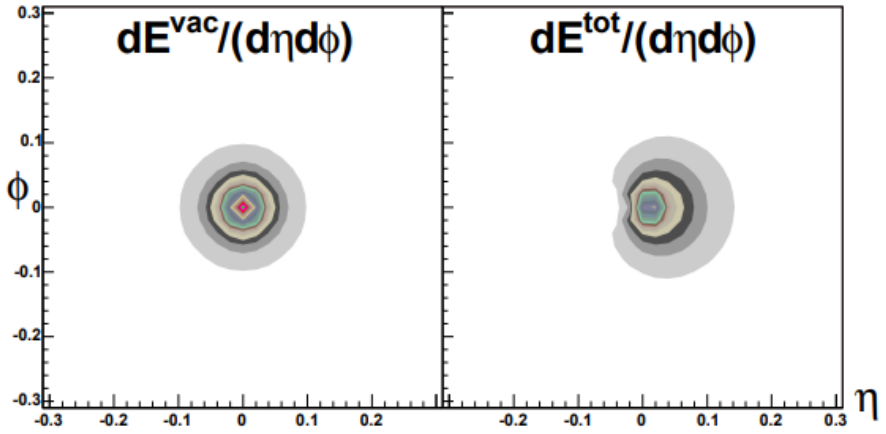
Radial flow is the collective outward expansion of quark-gluon plasma driven by intense pressure gradients.





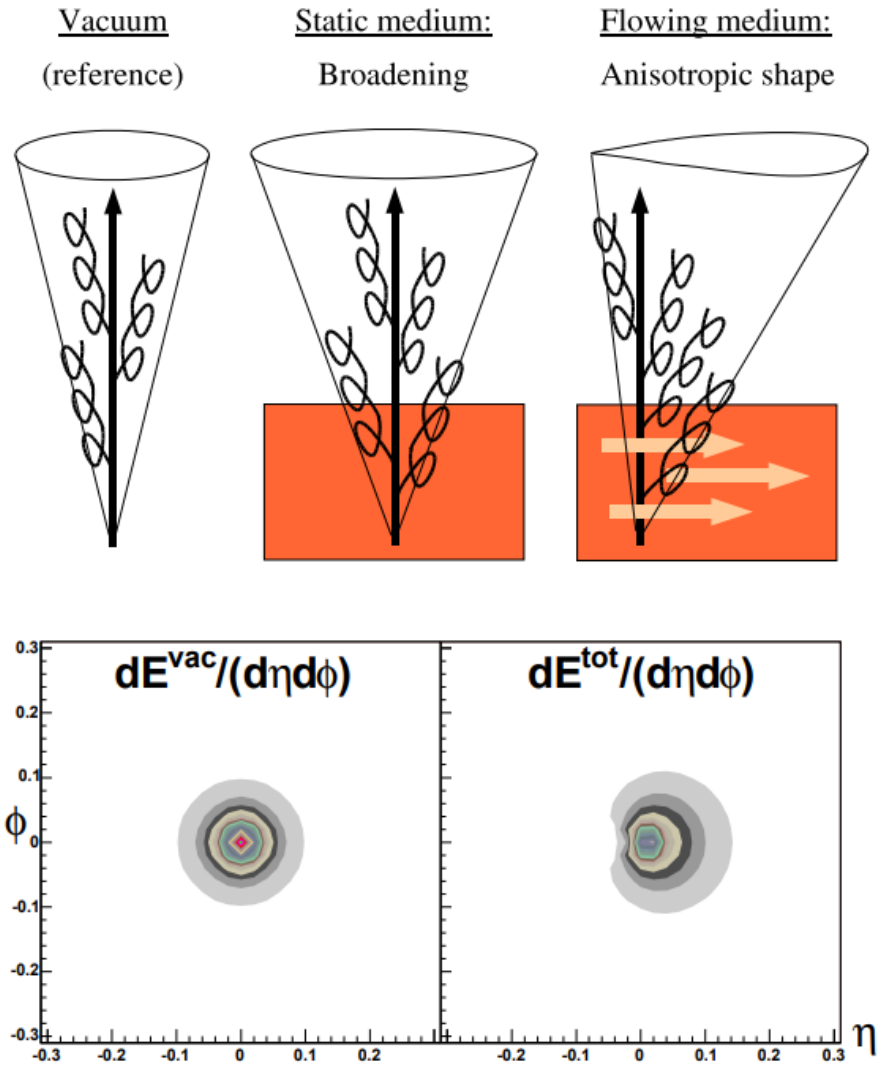
Intra-jet asymmetry (Jet winnowing)

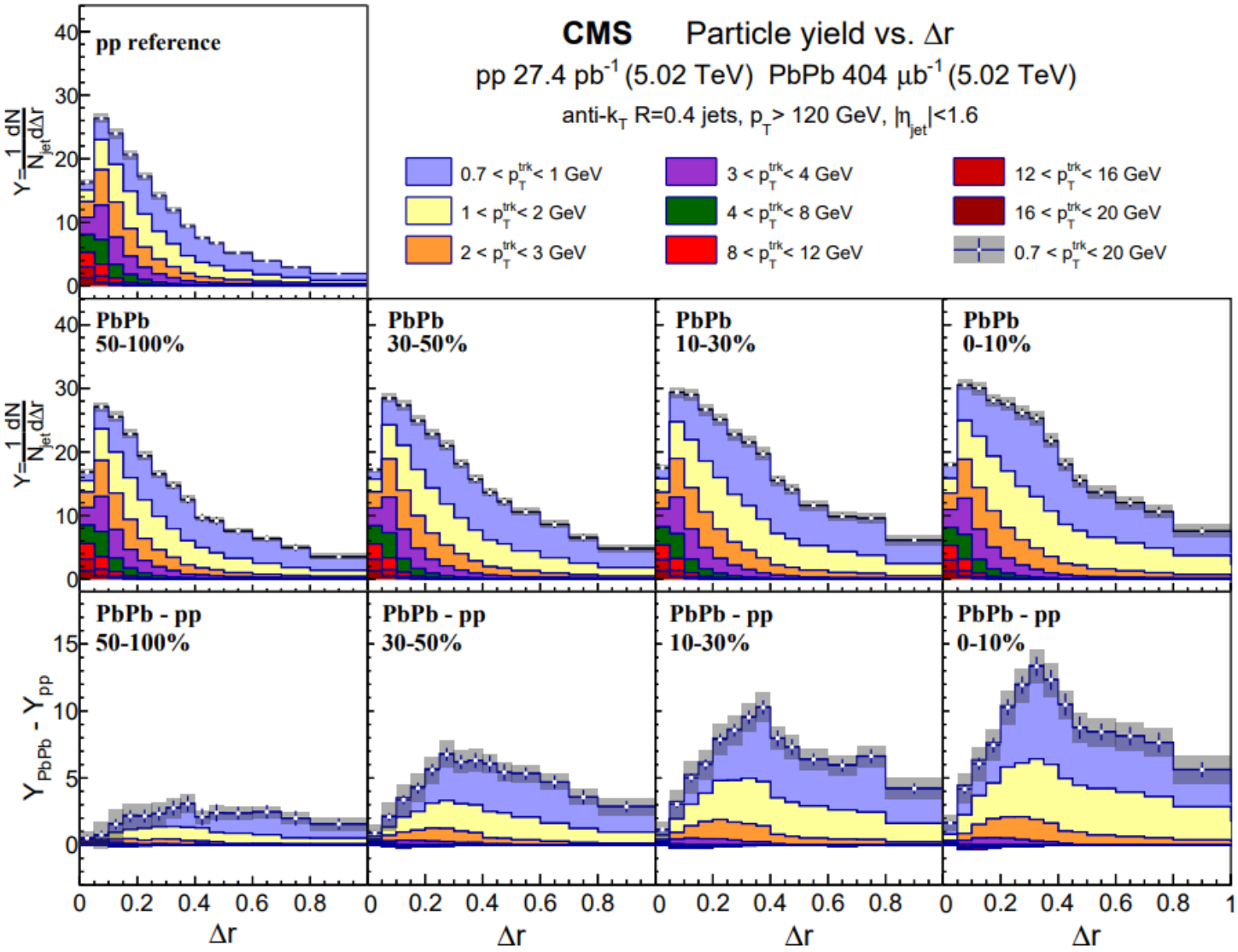




Armesto, Salgado, Wiedemann Phys.Rev.Lett.93:242301,2004

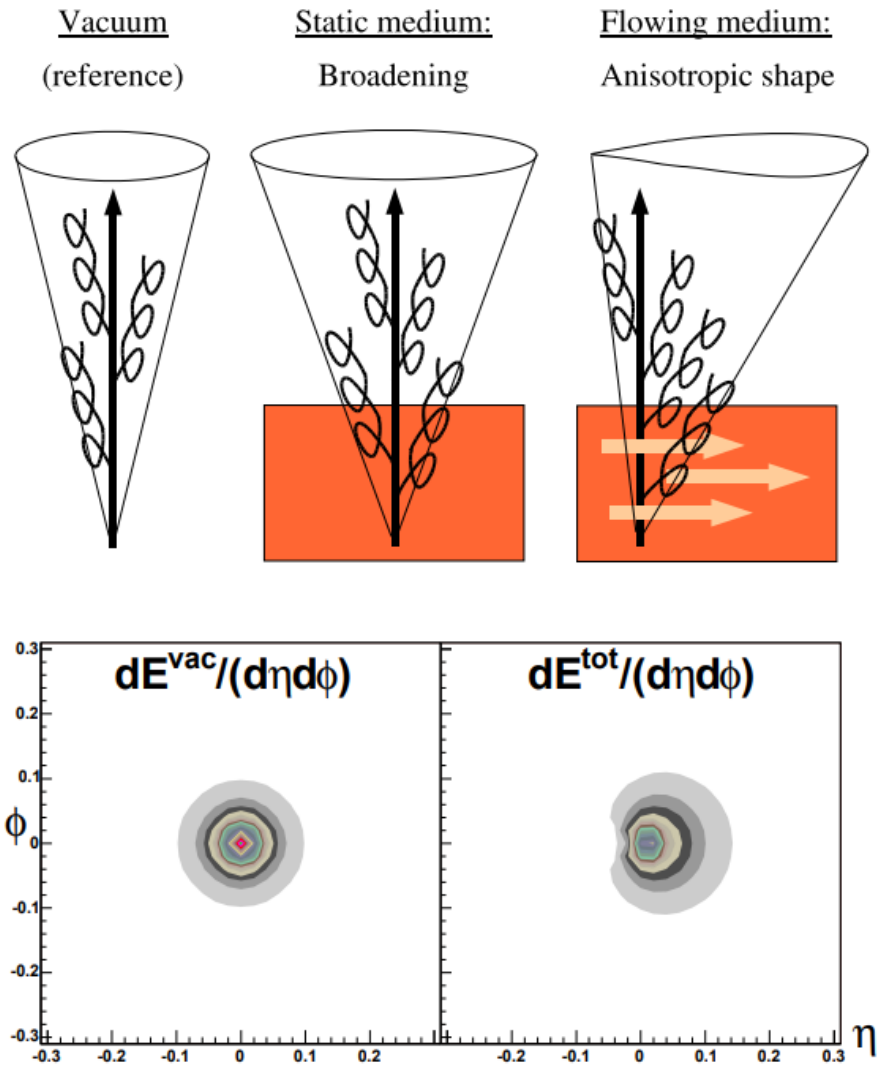
Intra-jet asymmetry (The jet-flow coupling)





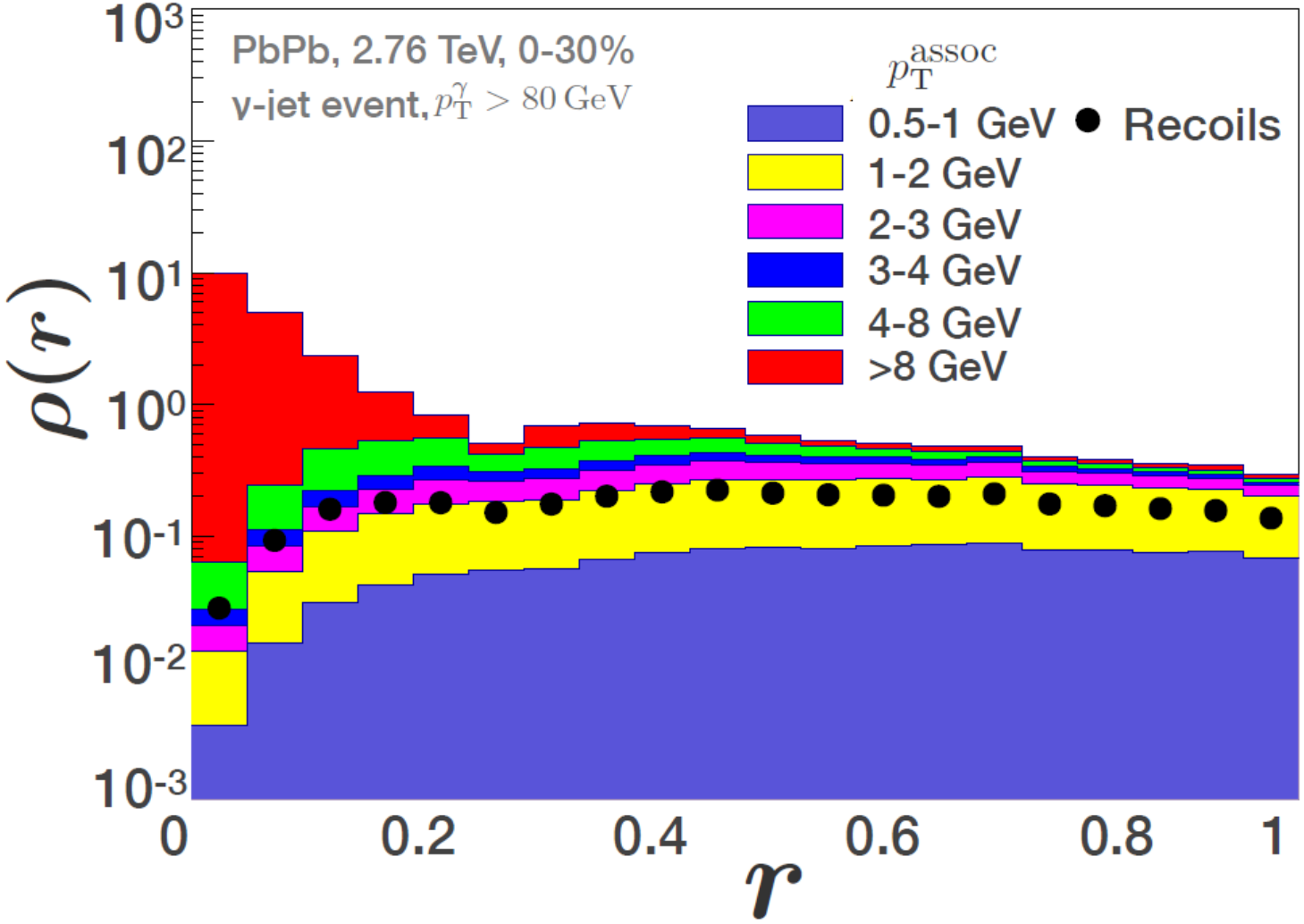
Armesto, Salgado, Wiedemann Phys.Rev.Lett.93:242301,2004

Jet shape (LBT)

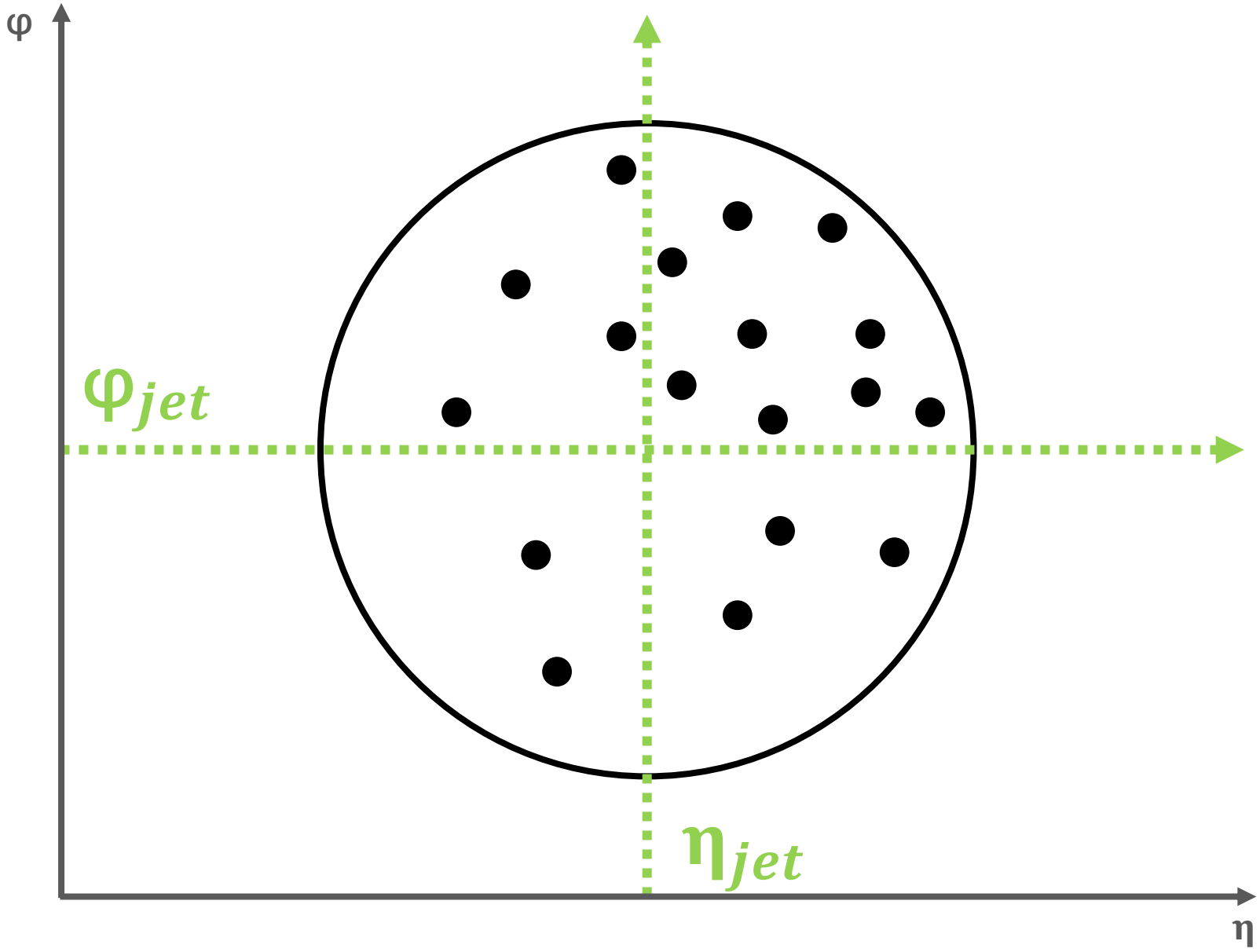


Armesto, Salgado, Wiedemann Phys.Rev.Lett.93:242301,2004

LBT Phys.Lett.B 782 (2018) 707-716



Intra-jet asymmetry (The jet-flow coupling)

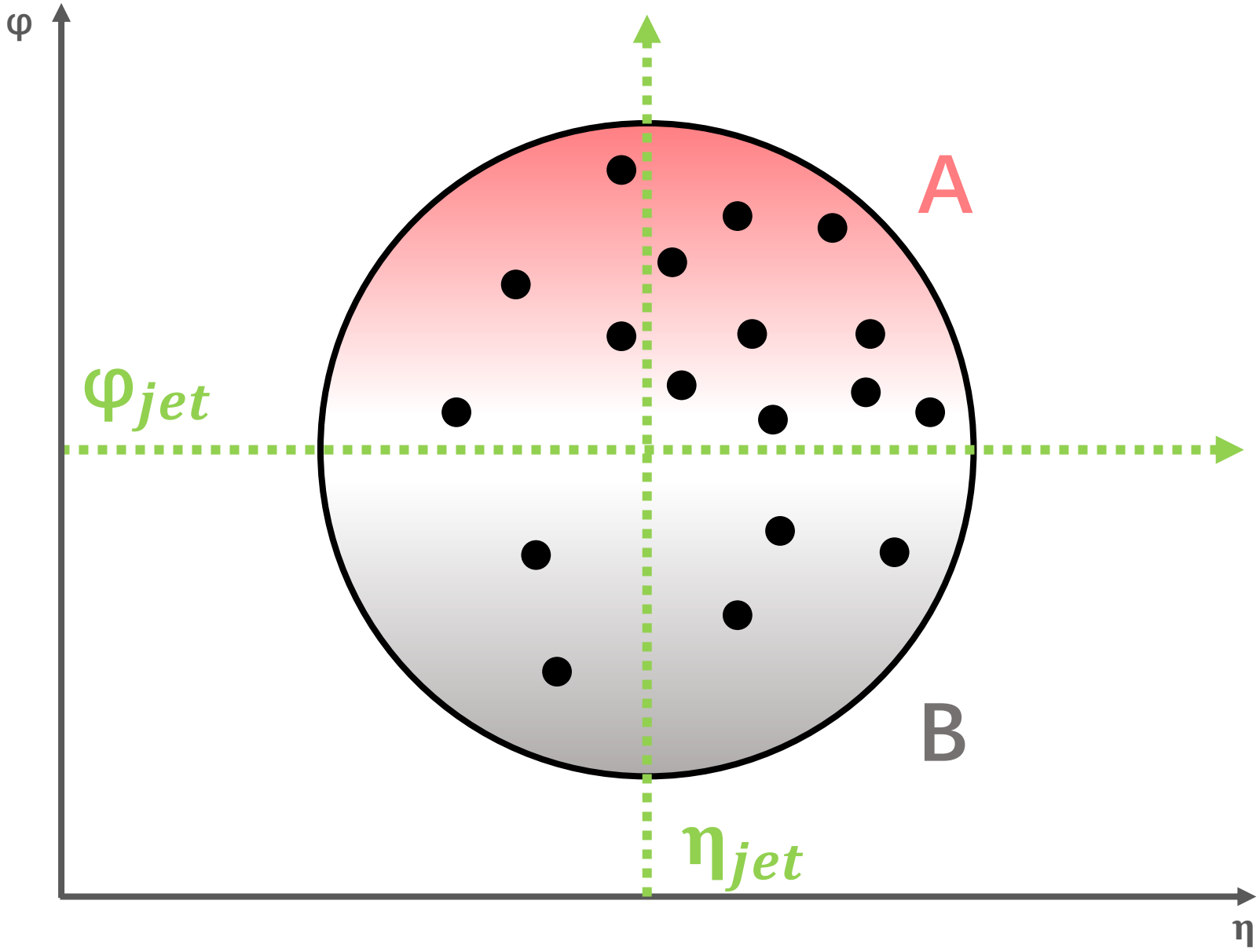


$$X = \frac{Q_A - Q_B}{Q_A + Q_B}$$

$$Q_A = \sum_{i \in A} p_{\perp i}$$

$$Q_B = \sum_{i \in B} p_{\perp i}$$

Intra-jet asymmetry (The jet-flow coupling)



$$X = \frac{Q_A - Q_B}{Q_A + Q_B}$$

$$Q_A = \sum_{i \in A} q_i$$
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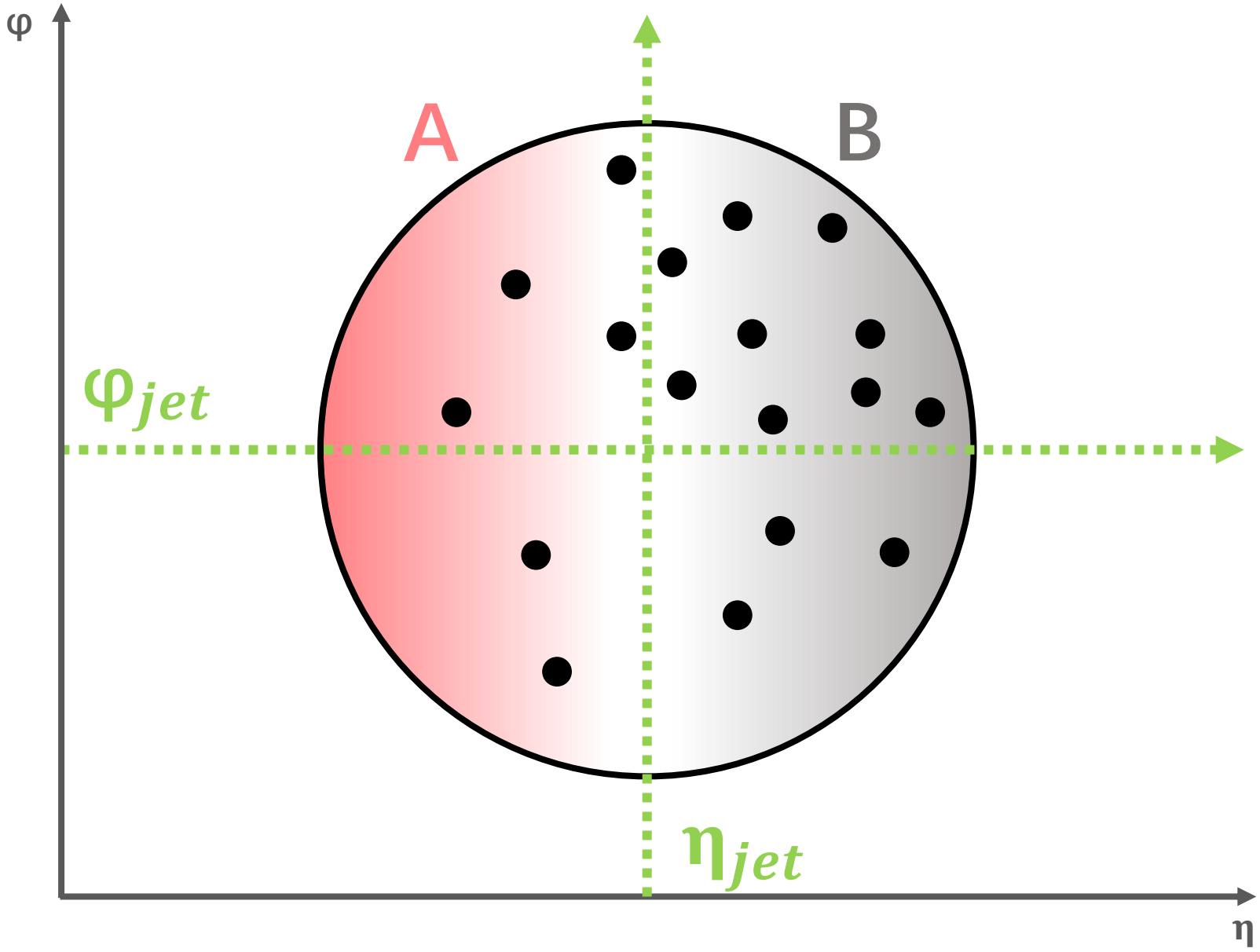
A $(\varphi_i > \varphi_{jet})$

B $(\varphi_i < \varphi_{jet})$

Intra-jet asymmetry (The jet-flow coupling)



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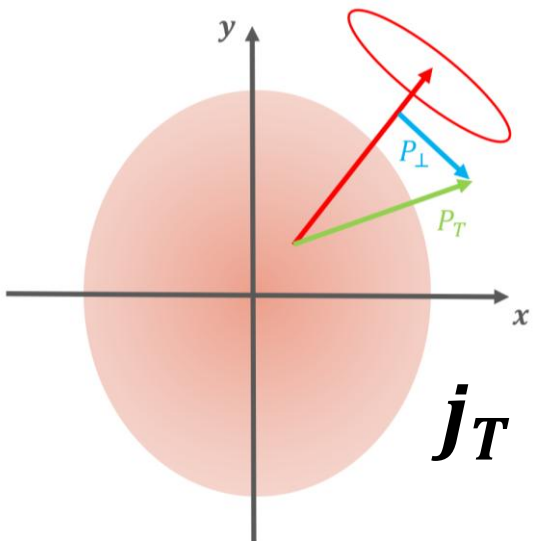
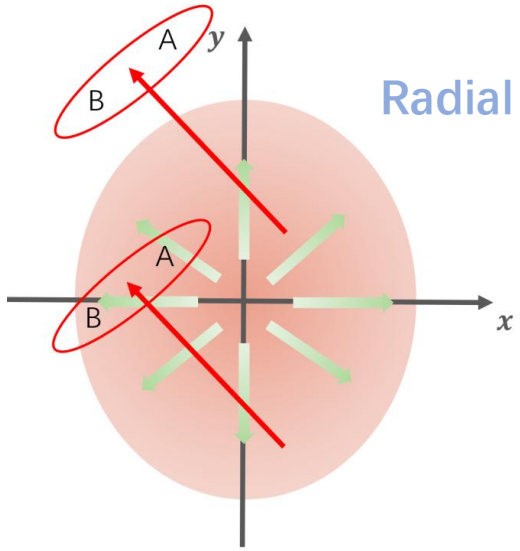
A $(\eta_i > \eta_{jet})$

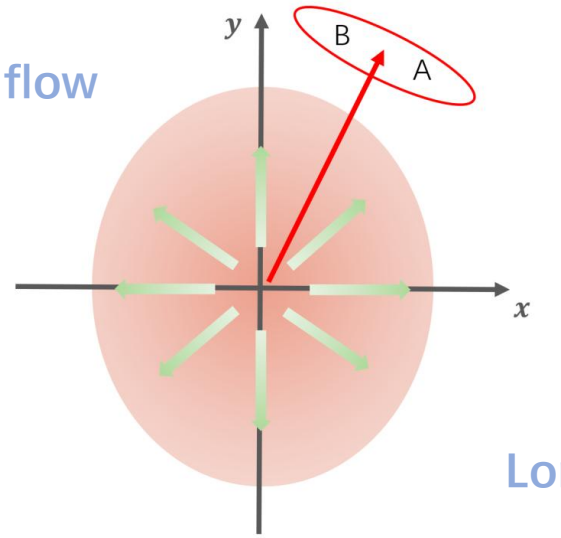
B $(\eta_i < \eta_{jet})$

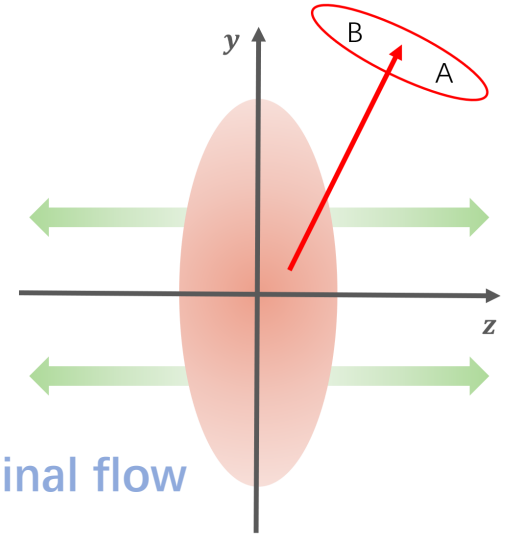
Intra-jet asymmetry in AA & pp collisions (γ-jet)





Radial flow

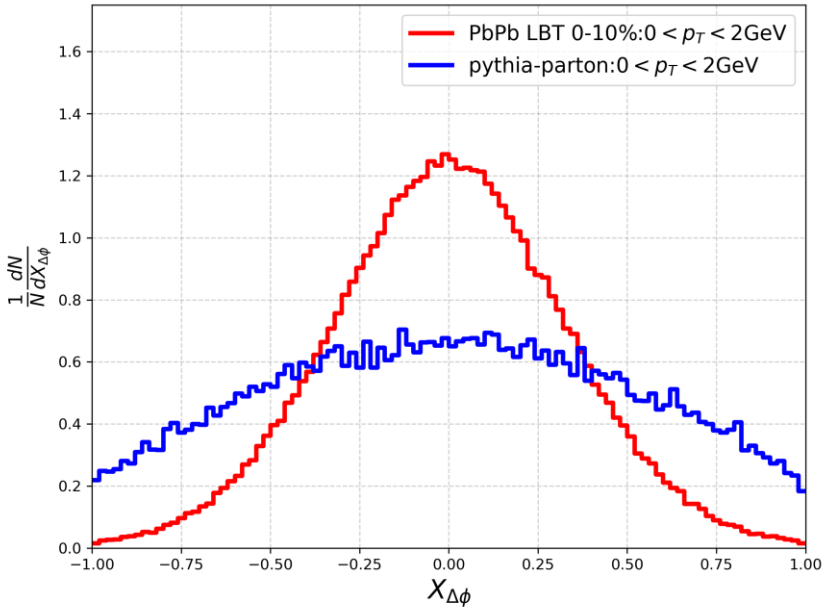


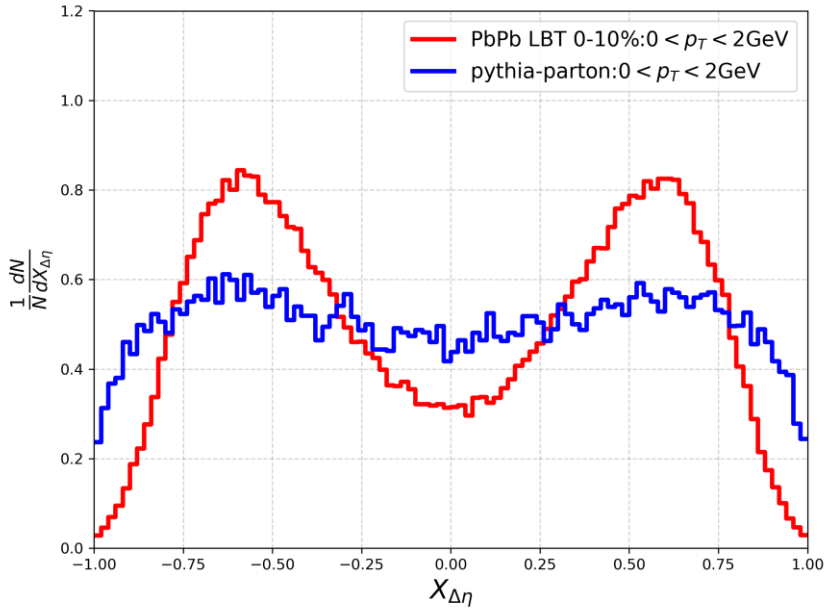


Longitudinal flow

Flow .vs. Fluctuation

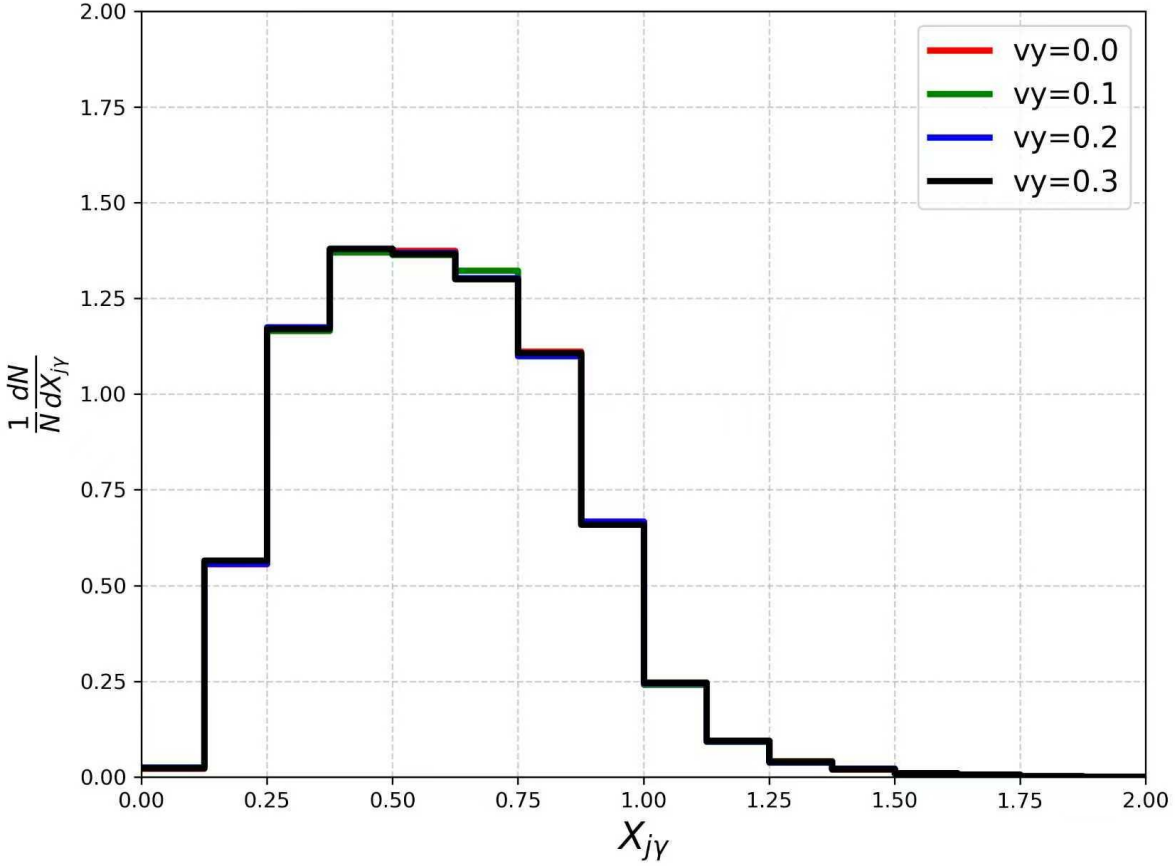
Increased jet multiplicity in AA collisions produces more symmetric jets than in pp.

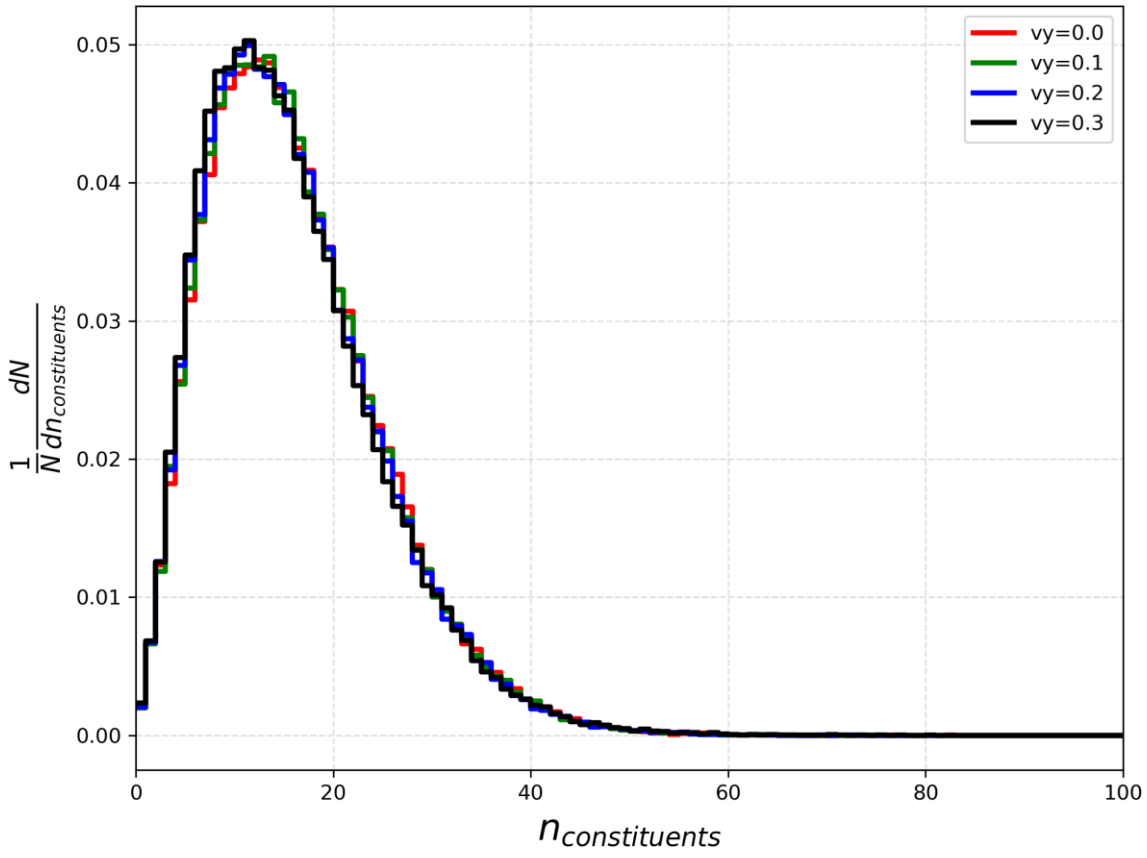




Intra-jet asymmetry & Jet-flow coupling (γ-jet)

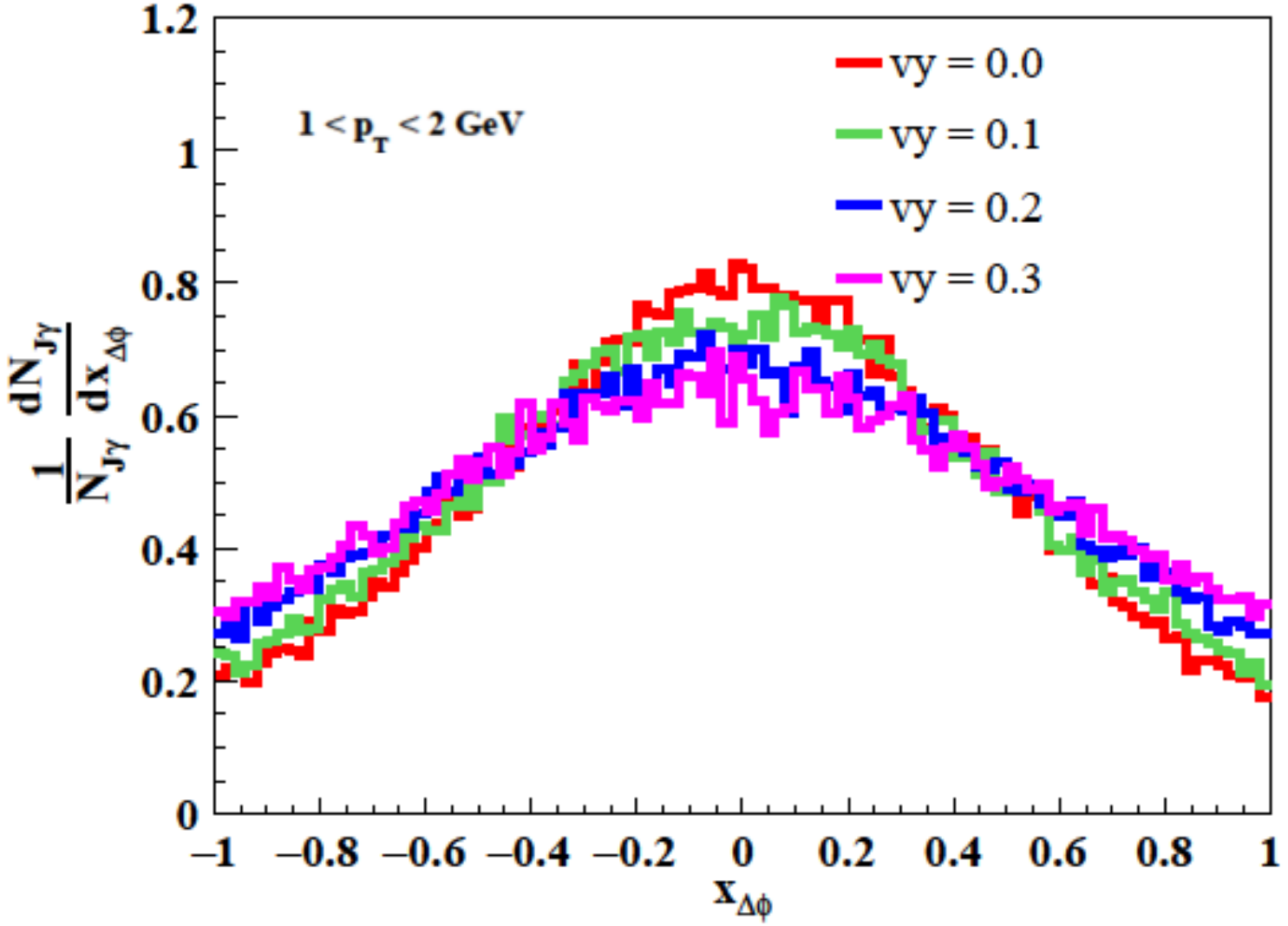
- Jet propagation in a uniform medium with different flow velocities.
  (Random jet directions & fixed flow direction)
- Jet energy loss and multiplicity distributions with different flow velocities.





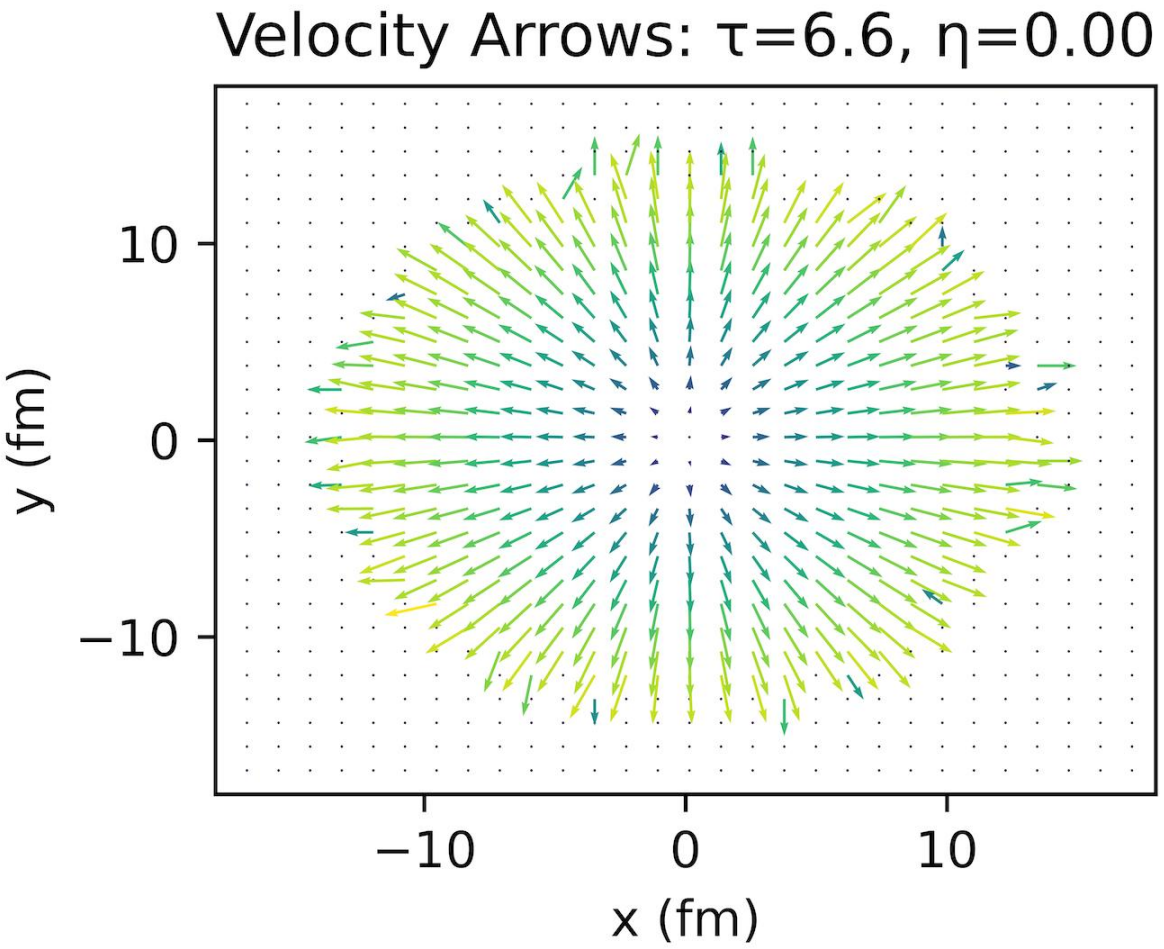
Intra-jet asymmetry & Jet-flow coupling (γ-jet)

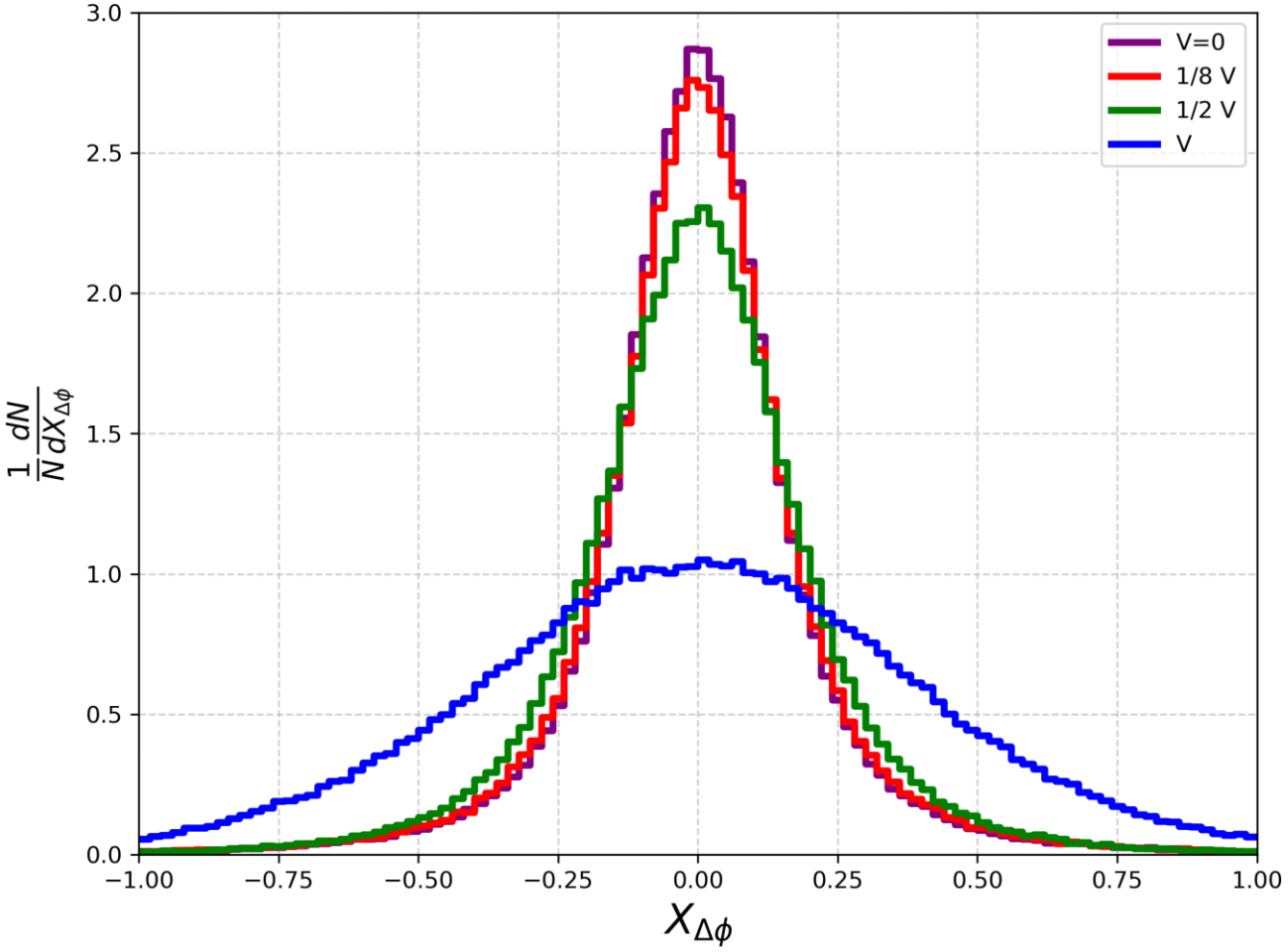
- A clear broadening of the intra-jet asymmetry with the increasing flow velocities.



Intra-jet asymmetry & Jet-flow coupling (γ-jet)

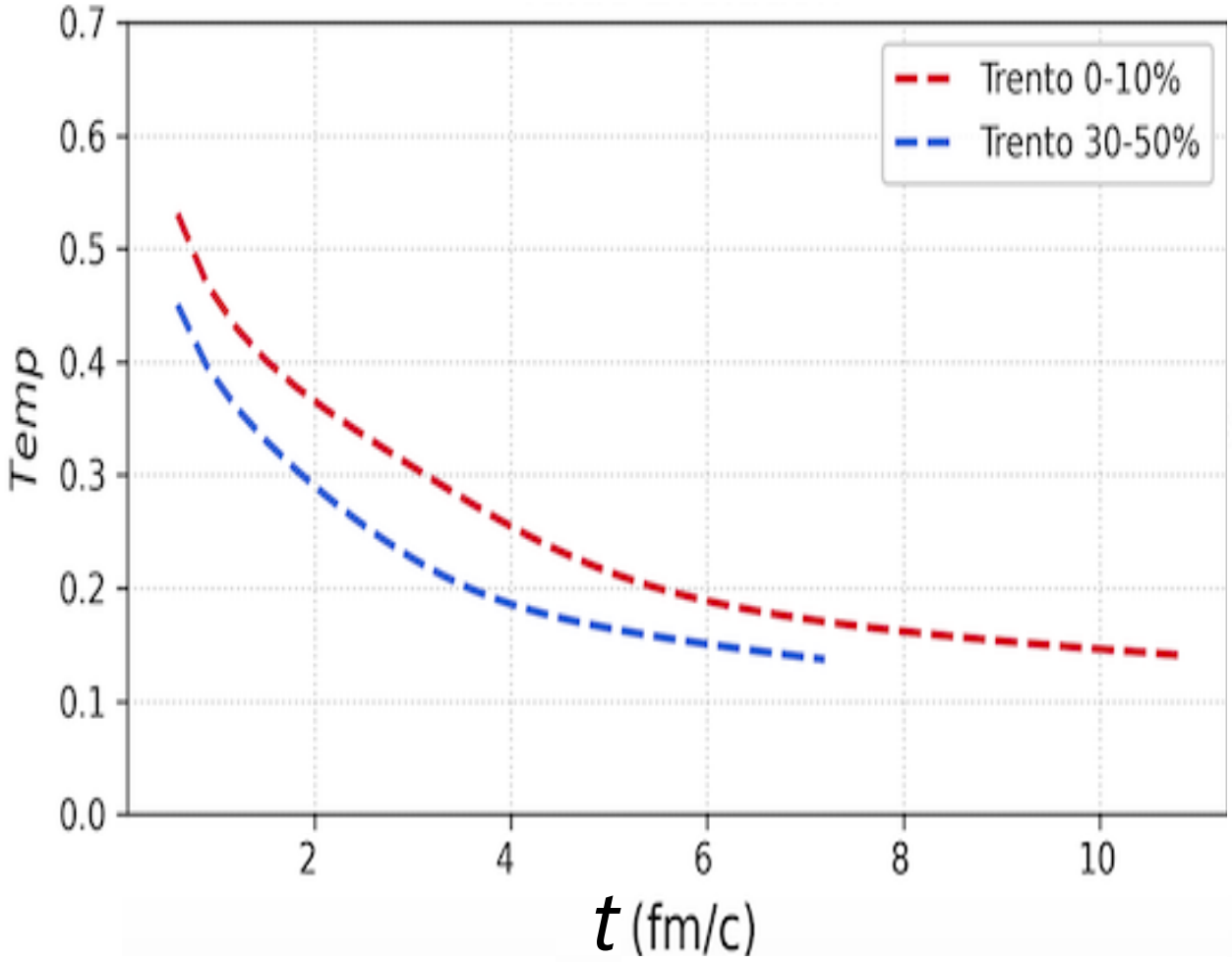
- Jet propagation in a flowing medium with different flow velocities.

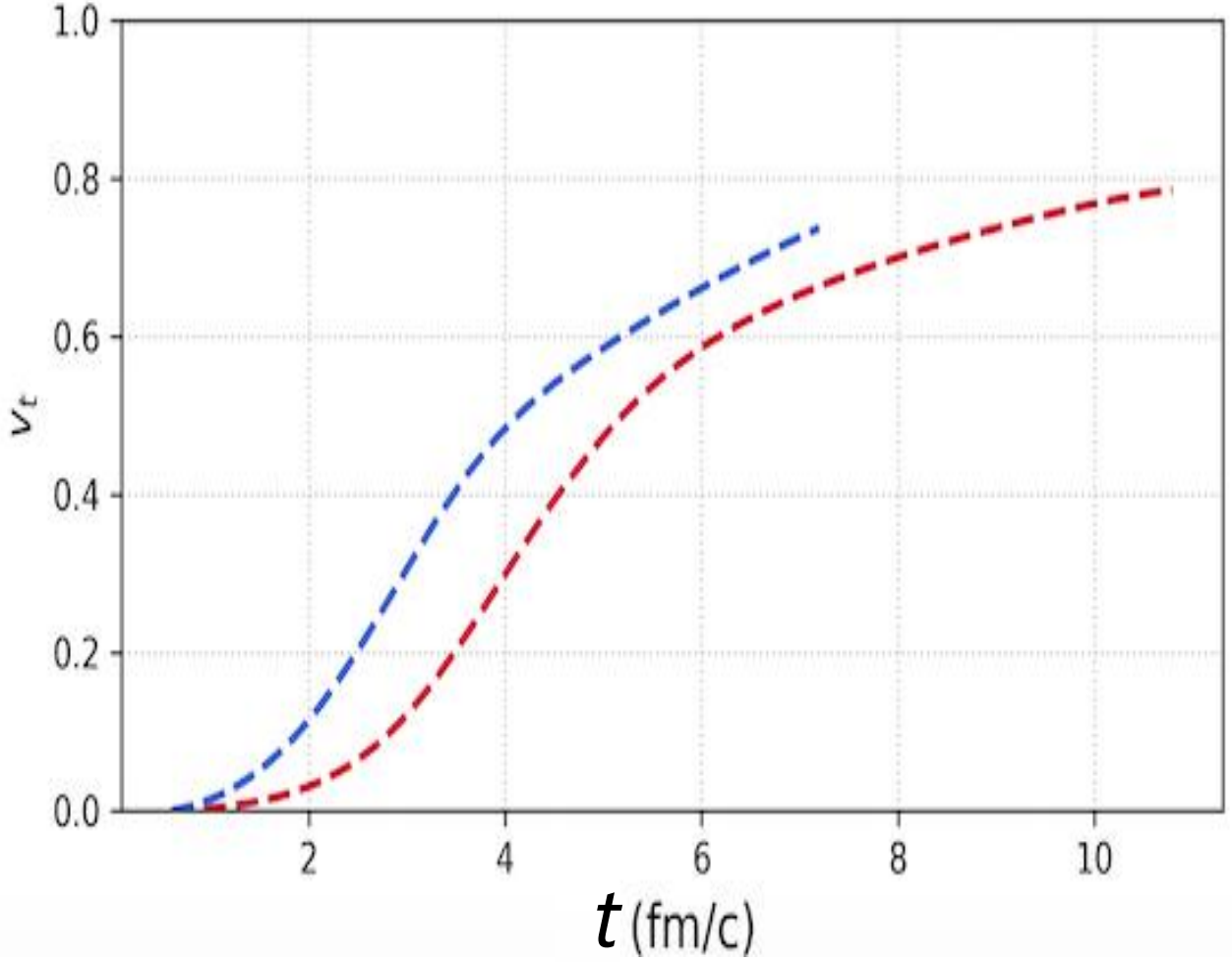




Intra-jet asymmetry & Jet-flow coupling (γ-jet)

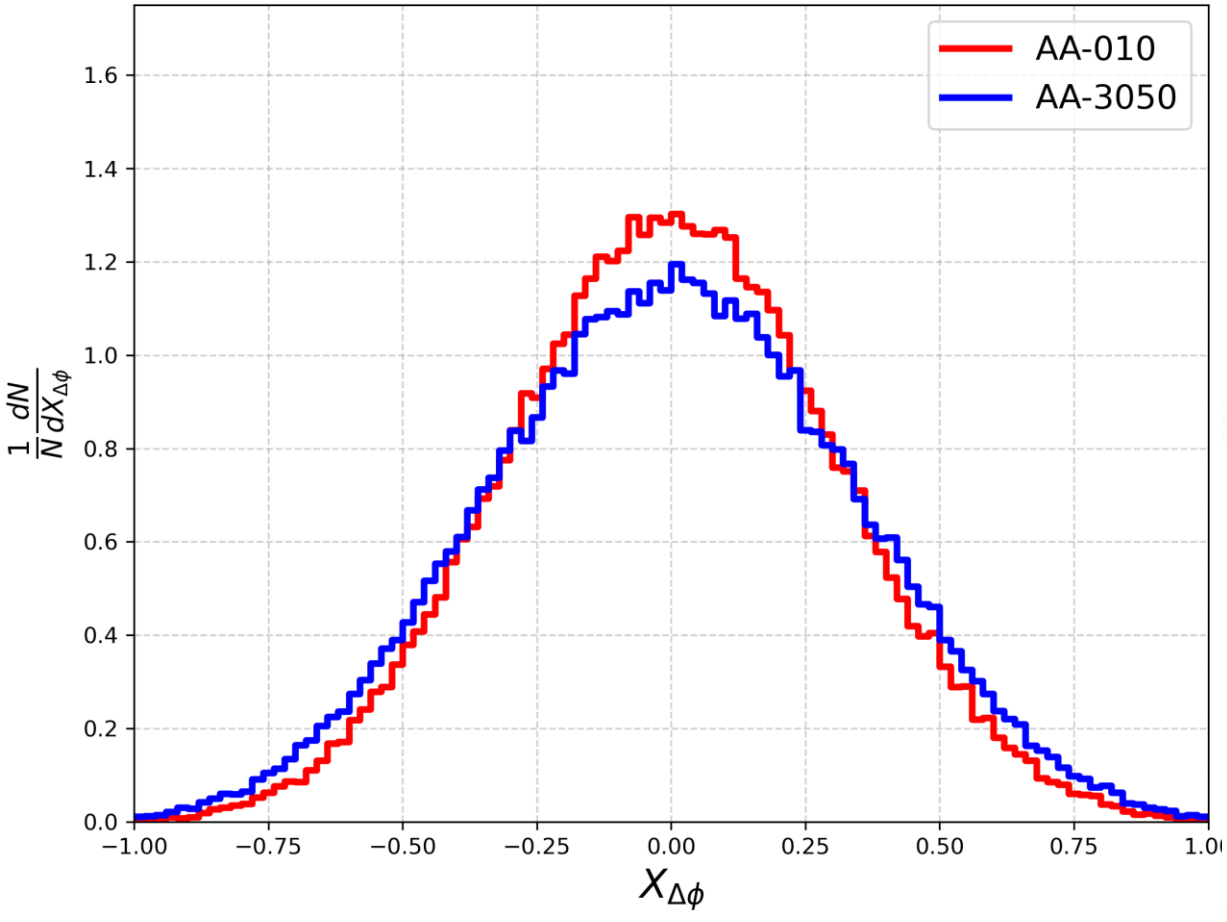
- The temperature and flow velocity experienced by a jet as a function of time during its propagation along the Y-axis from the original point at different centralities.

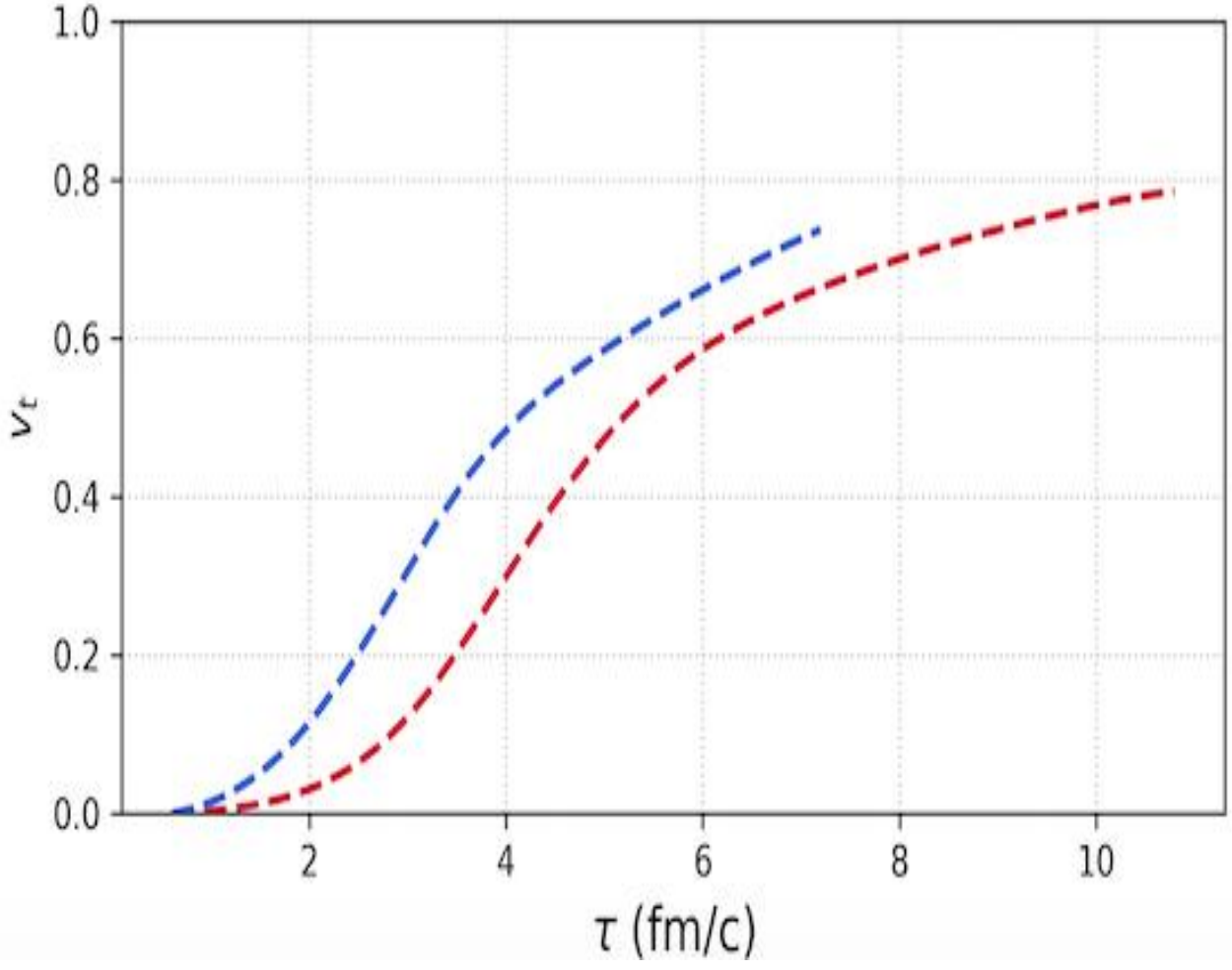




Intra-jet asymmetry & Jet-flow coupling (γ-jet)

- Broadening of the intra-jet asymmetry at different centralities.

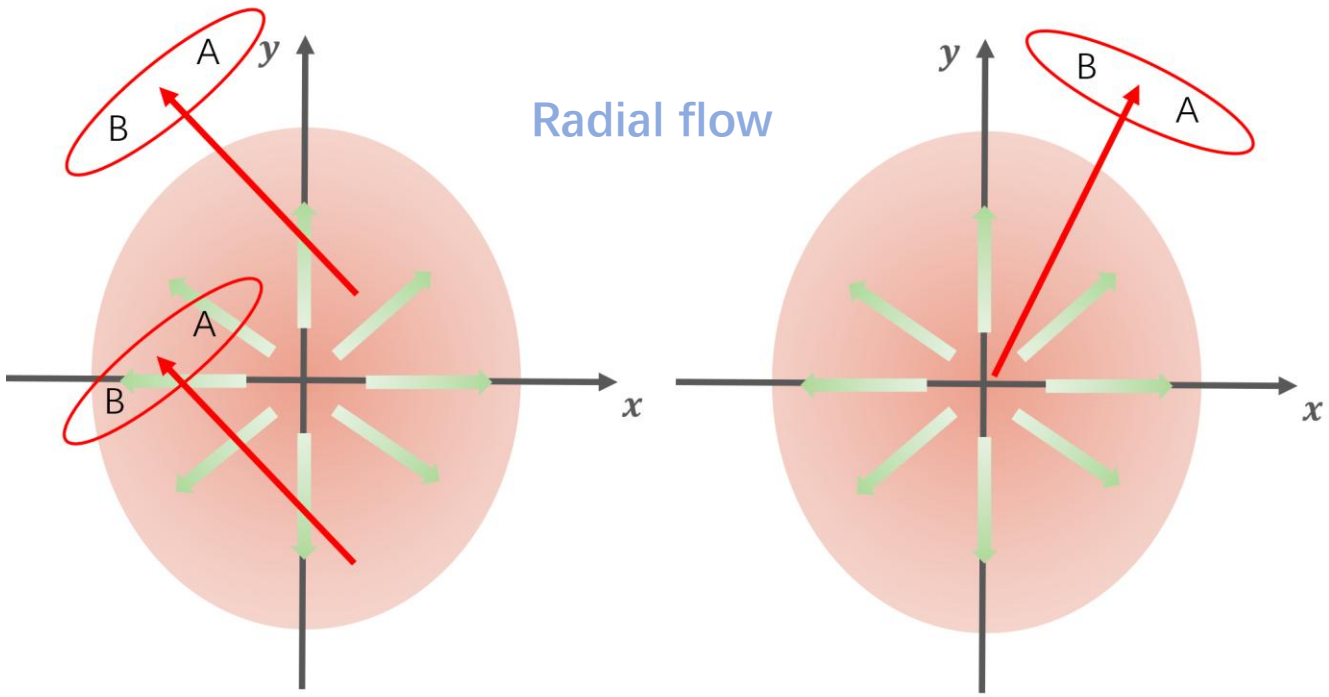


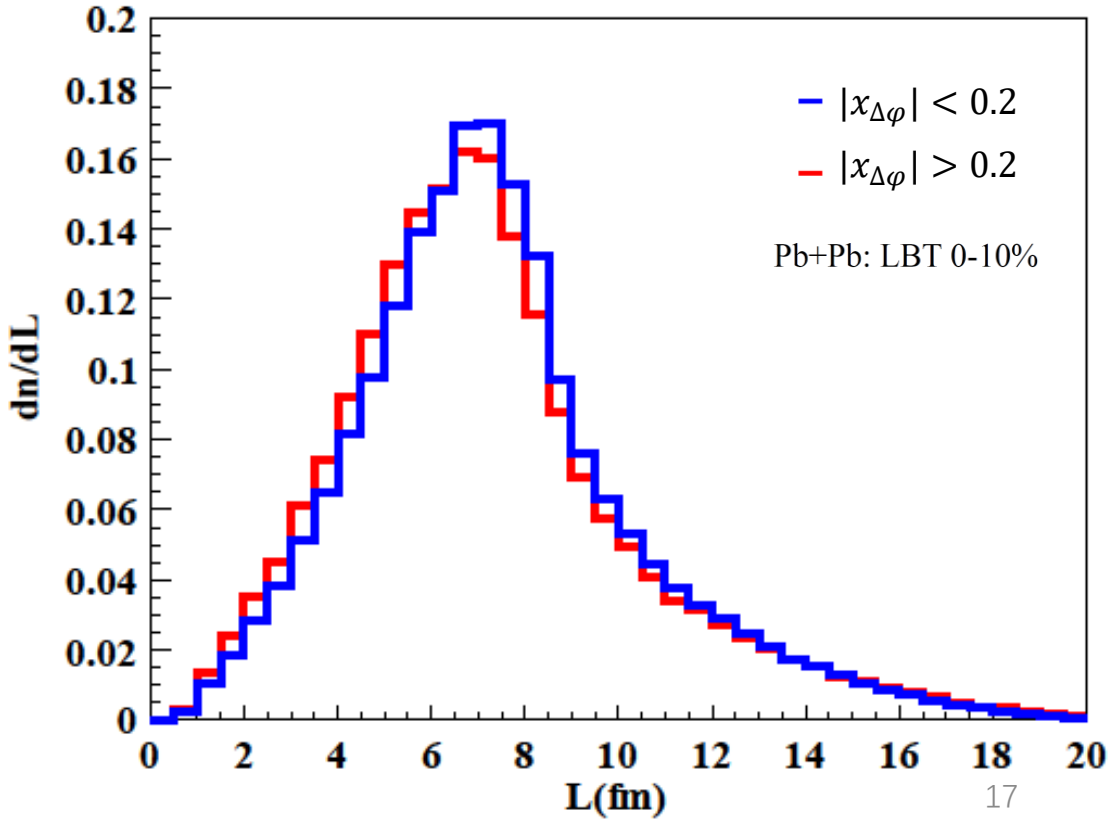


Intra-jet asymmetry in AA collisions (γ-jet)

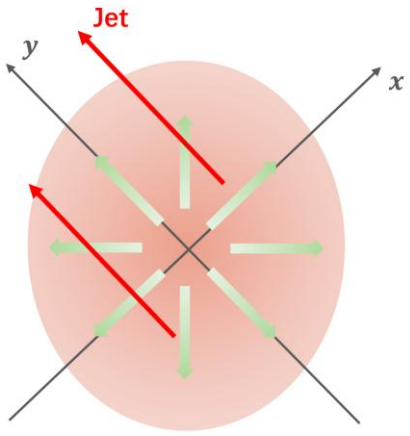
- Jets propagating perpendicularly to the flow will suffer stronger distortion.

- In average, the path length of the jets with larger asymmetry will be slightly shorter compared to jets that are more symmetric.

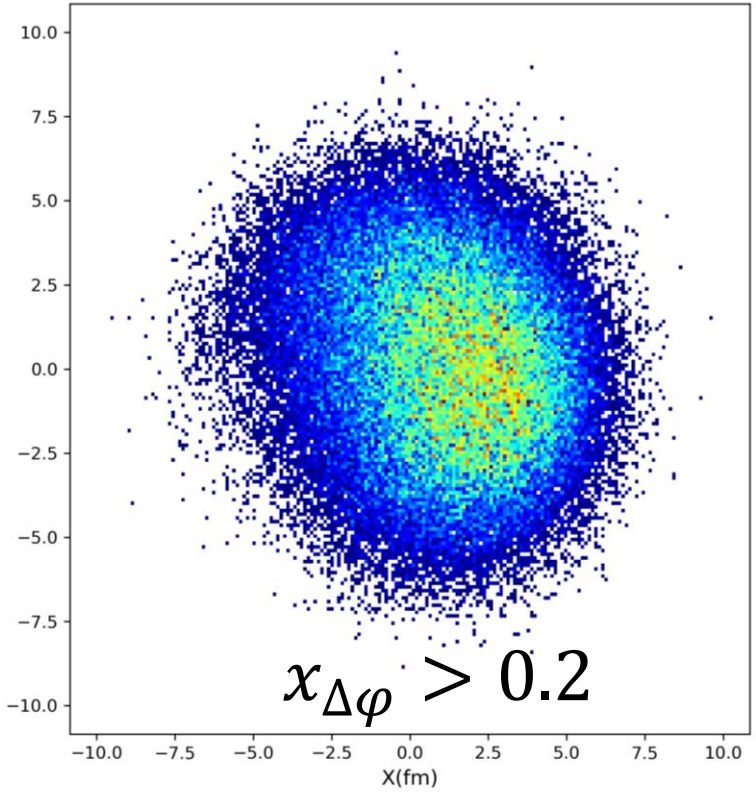


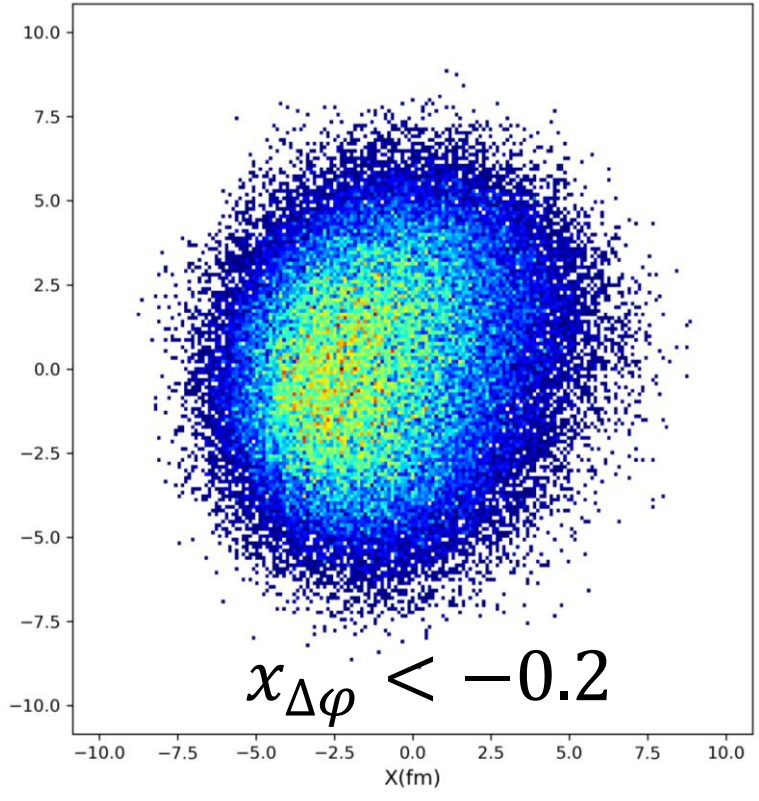


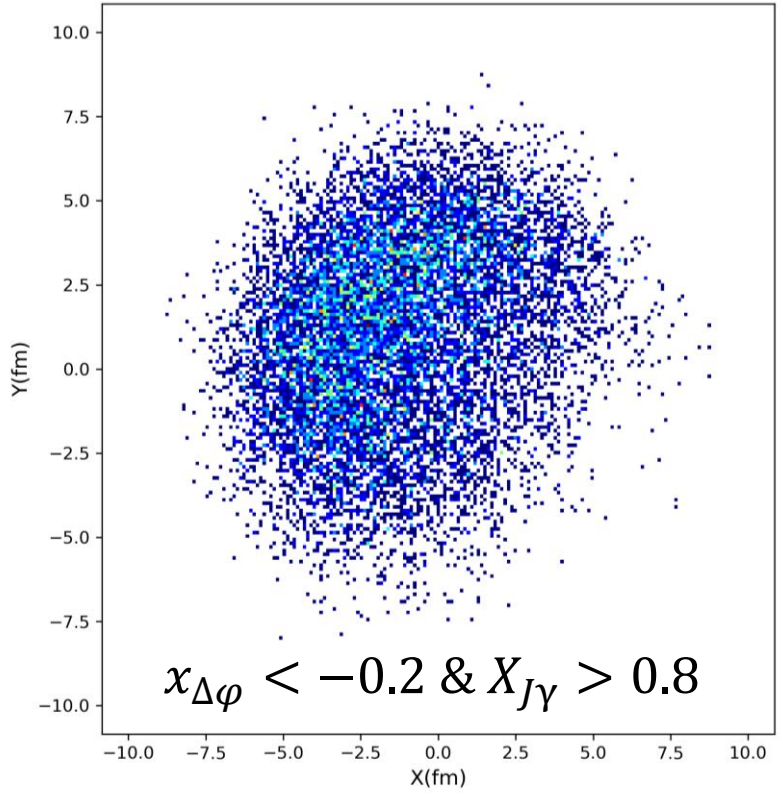
Jet localization with intra-jet asymmetry (γ-jet)



- Since the relative angle between jet and the event plane is random, we can use the jet axis as the coordinate axis y in the transverse plane.
- Better localization in multiple jets (Dijet) events.



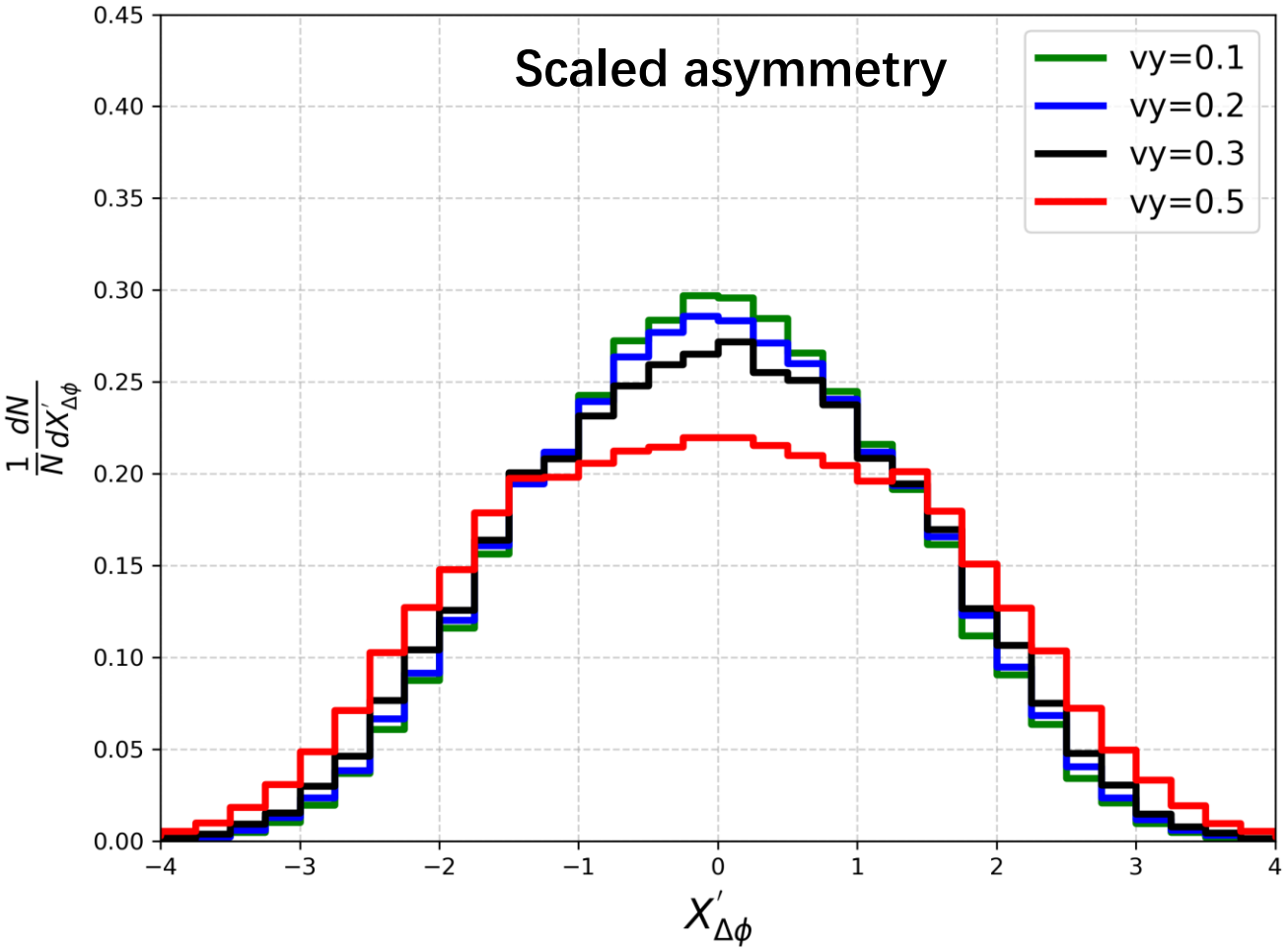




Summary

- A method to detect the effect of jet-flow coupling in heavy-ion collisions.
- Intra-jet asymmetry are observed at both the longitudinal and transverse direction.
- Intra-jet asymmetry can also be used in jet localization in heavy-ion collisions

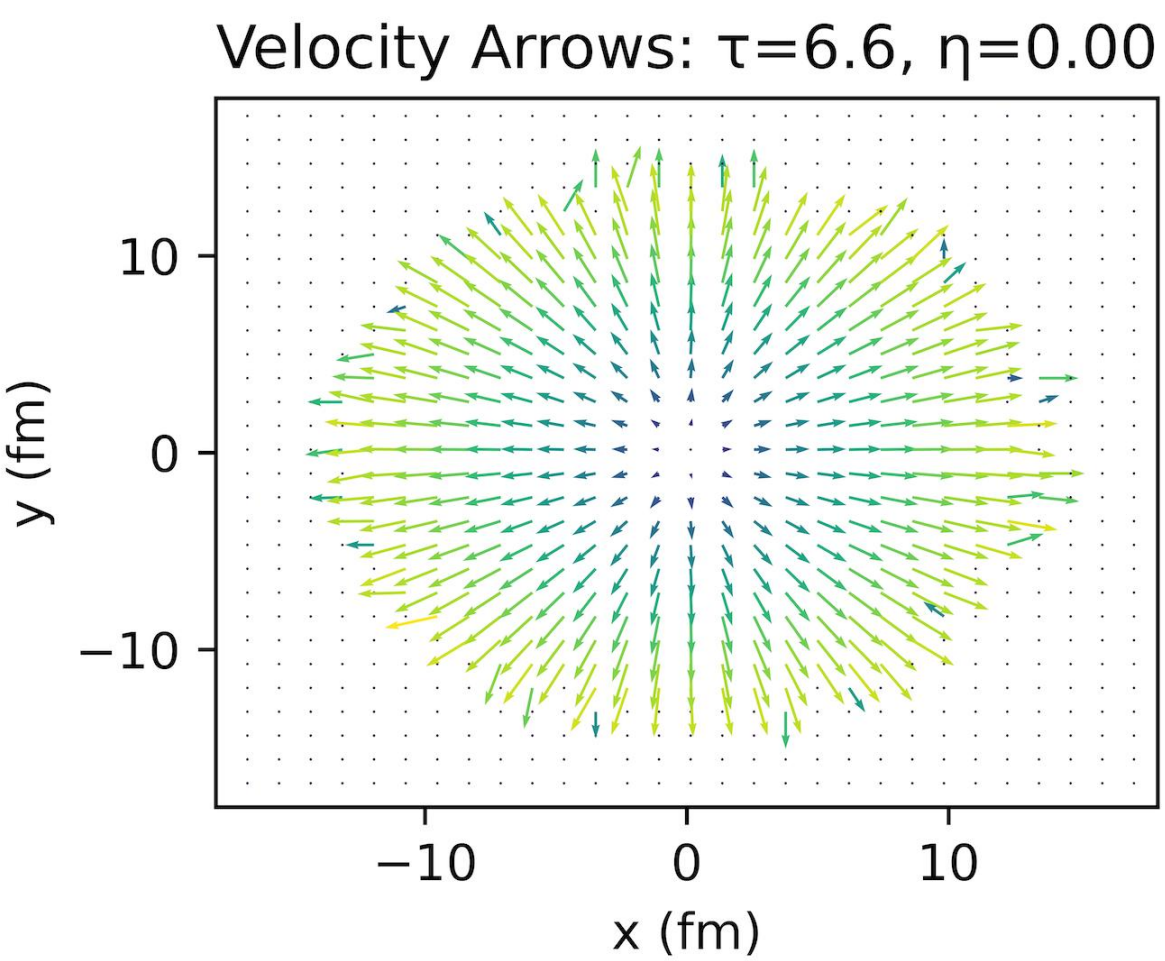
Flow .vs. Fluctuation

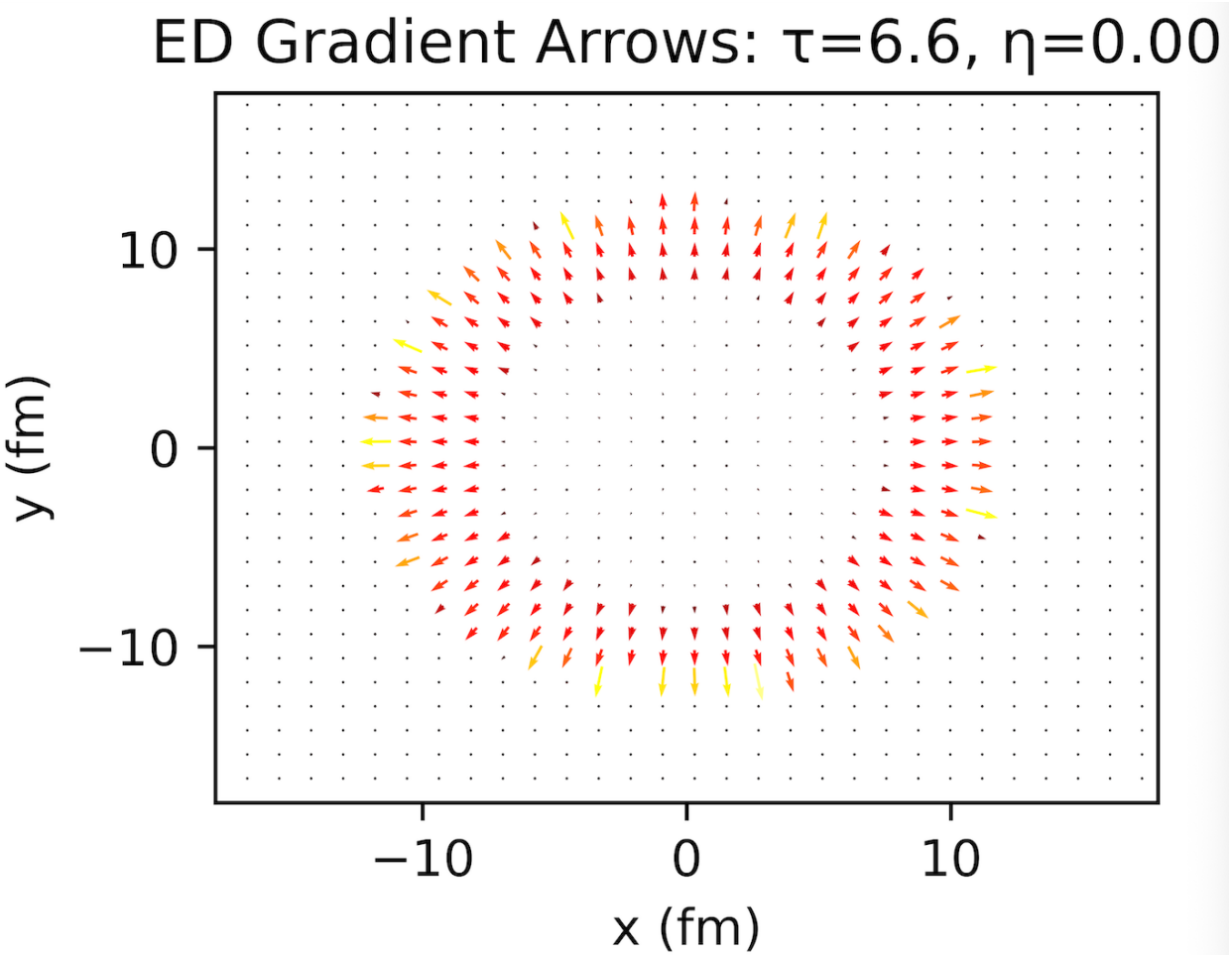


$$\mathbf{X} = \frac{Q_A - Q_B}{Q_A + Q_B}$$

$$X' = \sqrt{M}\left(\frac{Q_A - Q_B}{Q_A + Q_B}\right)$$

Flow .vs. Energy density gradients

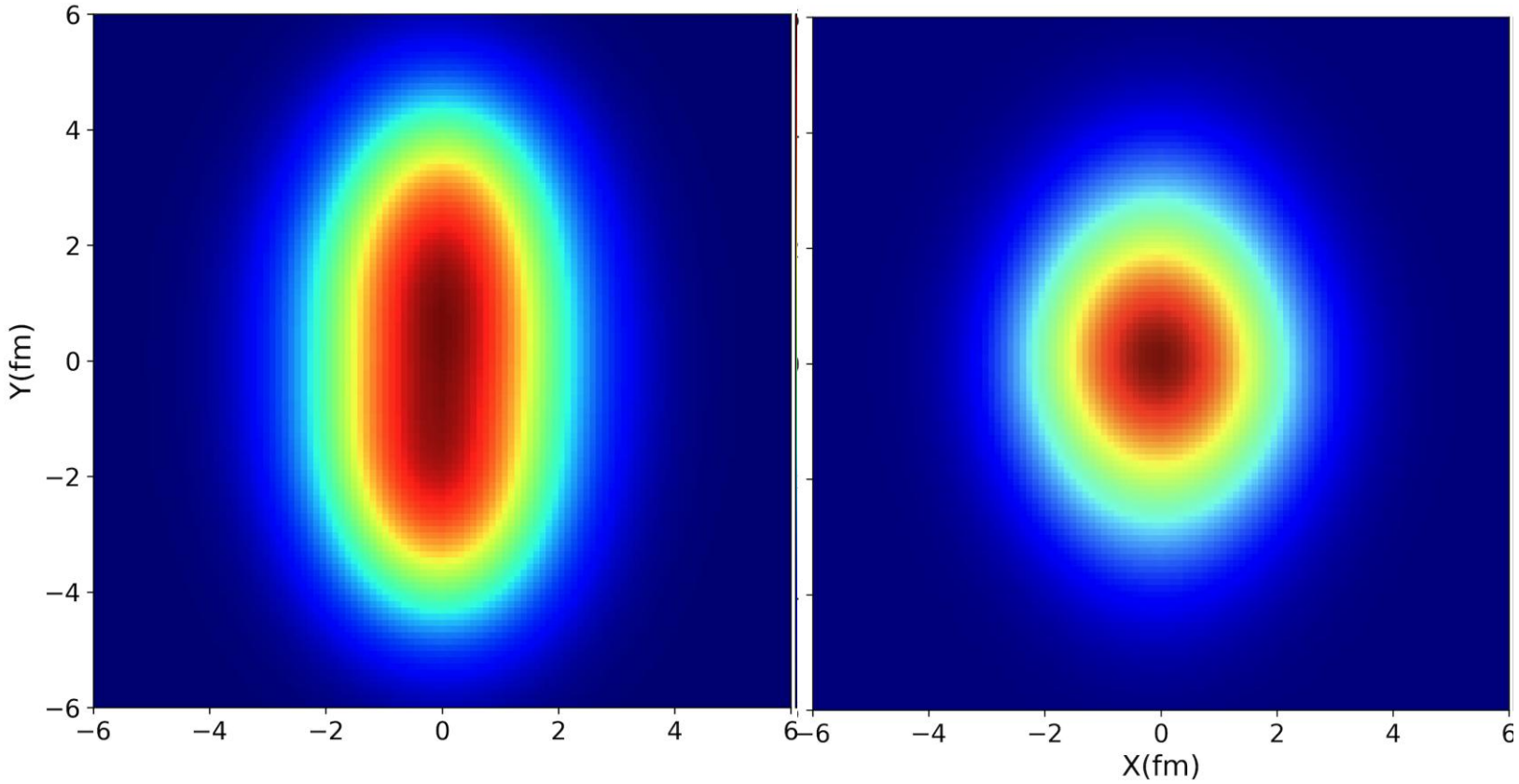


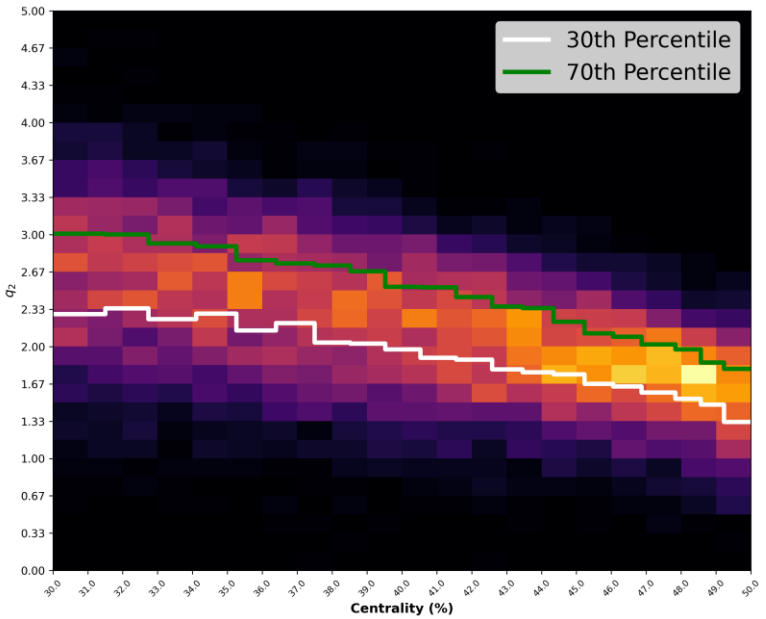


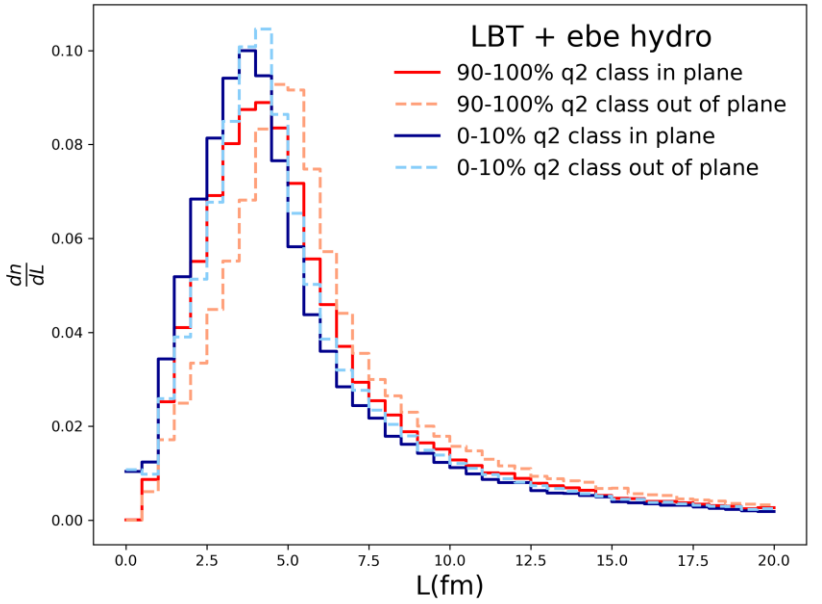
Event-shape engineering (ESE)

Increased jet multiplicity in AA collisions produces more symmetric jets than in pp.

Y. J. Huang, W. Dai, X. W. Hao, T. Luo, X. X. Liu, X. Y. Wu in preparation

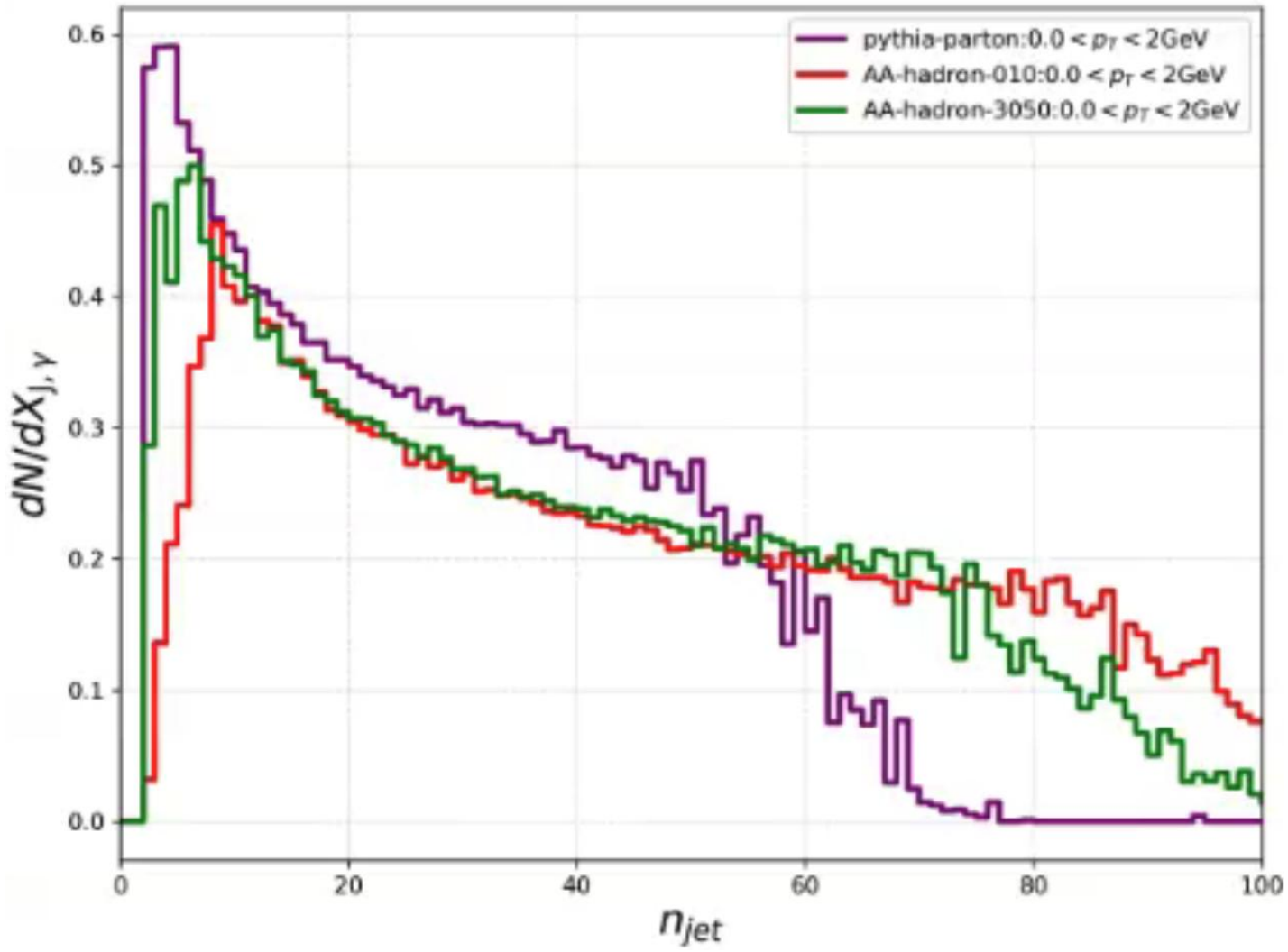






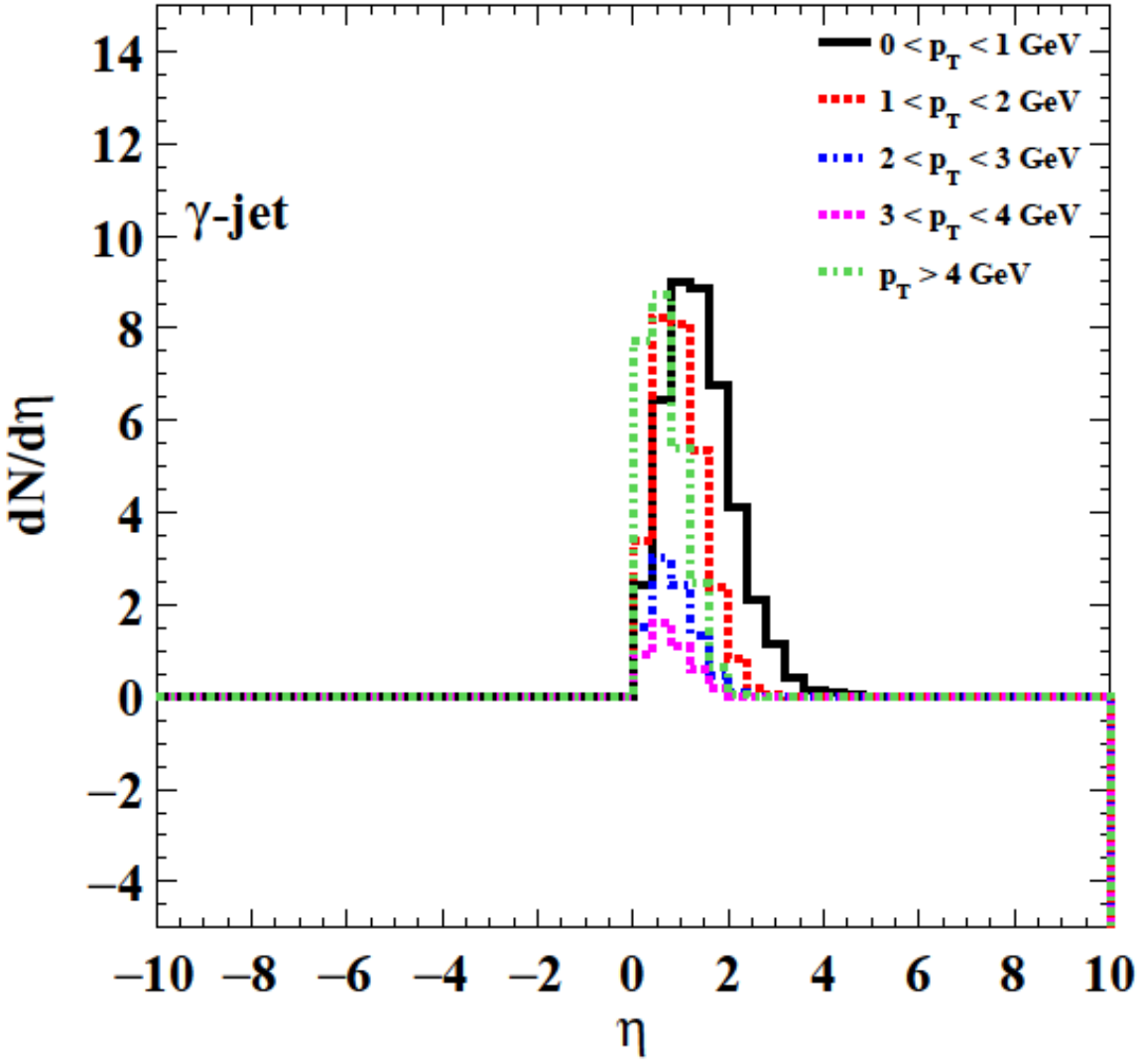

Thanks

Jet induced medium response: a naive picture



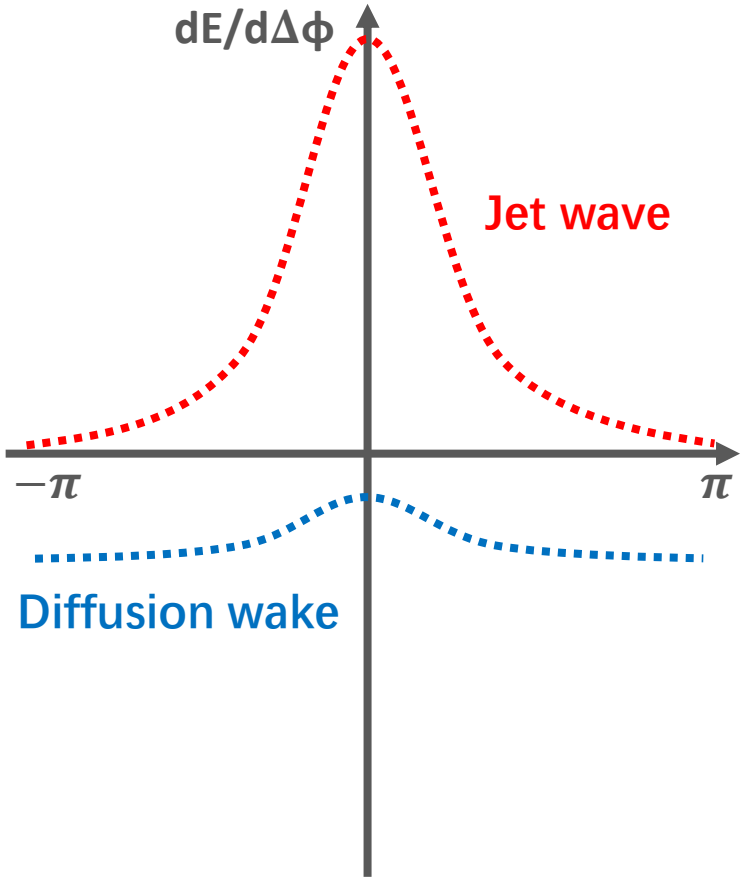
Intra-jet asymmetry (Jet winnowing)

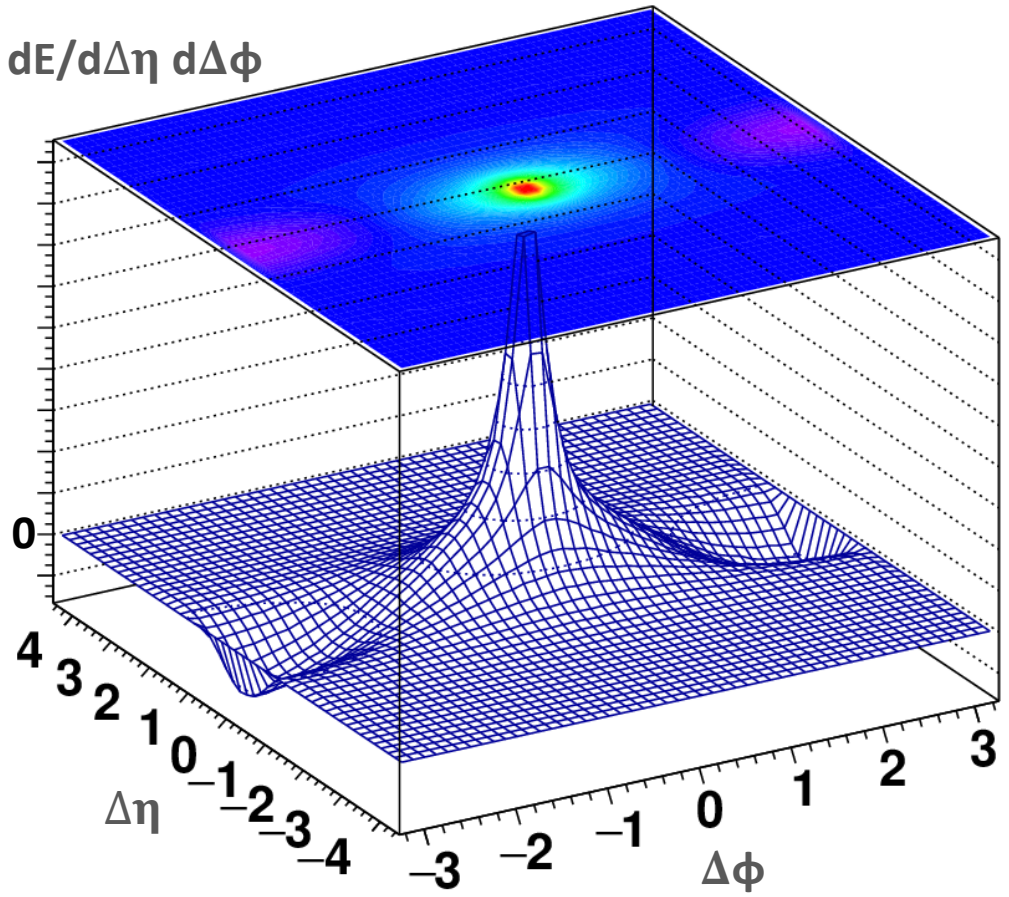
Jet side

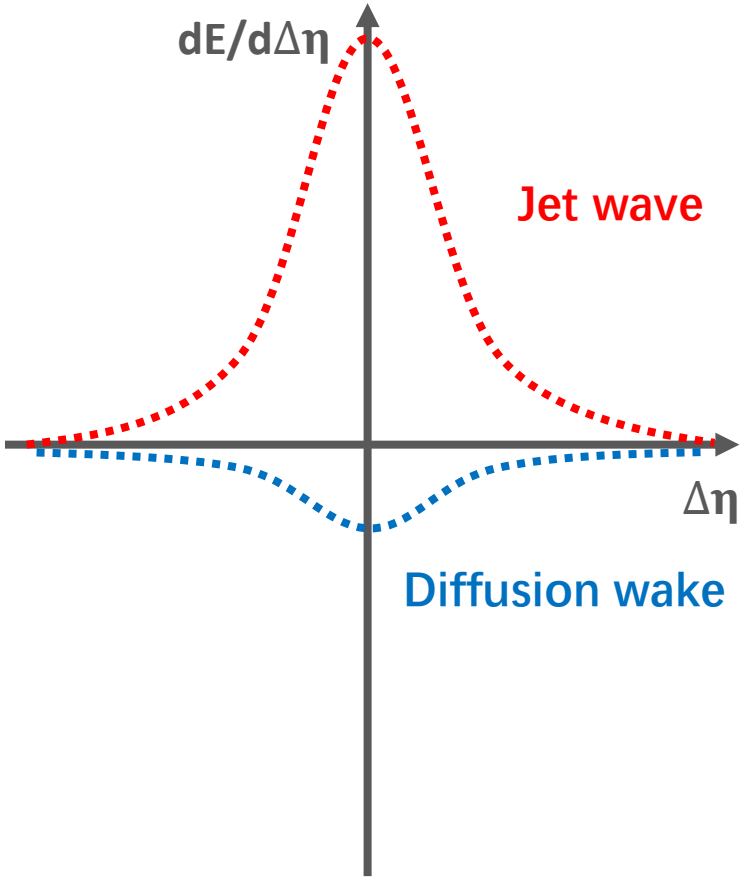


Jet induced medium response: a naive picture

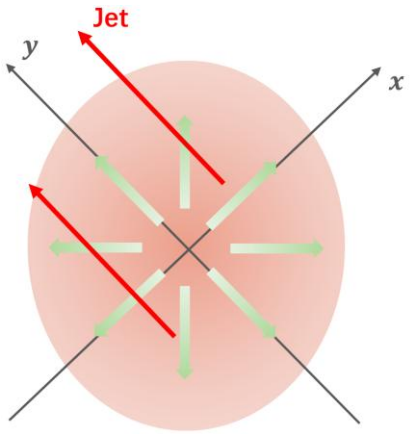
- The deep in the back side of the jet (Signal of the diffusion wake).
- The induced diffusion wake is locate at the same rapidity range as the jet.



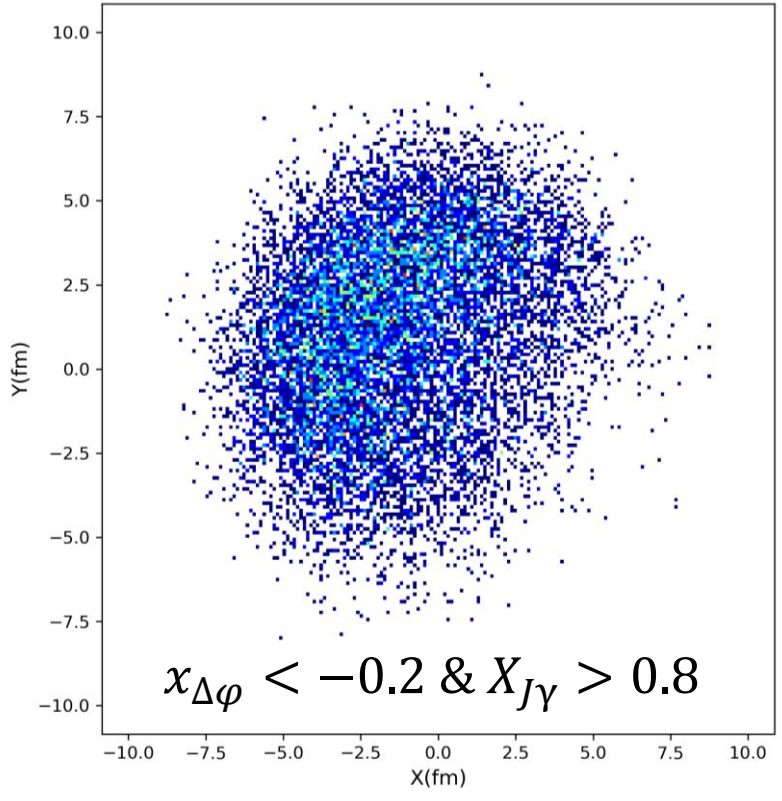


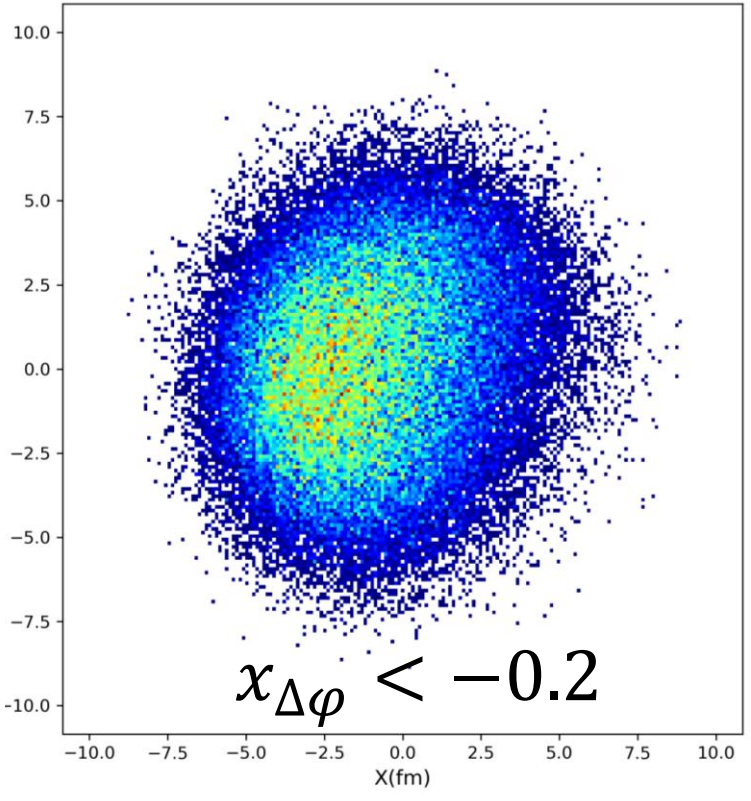


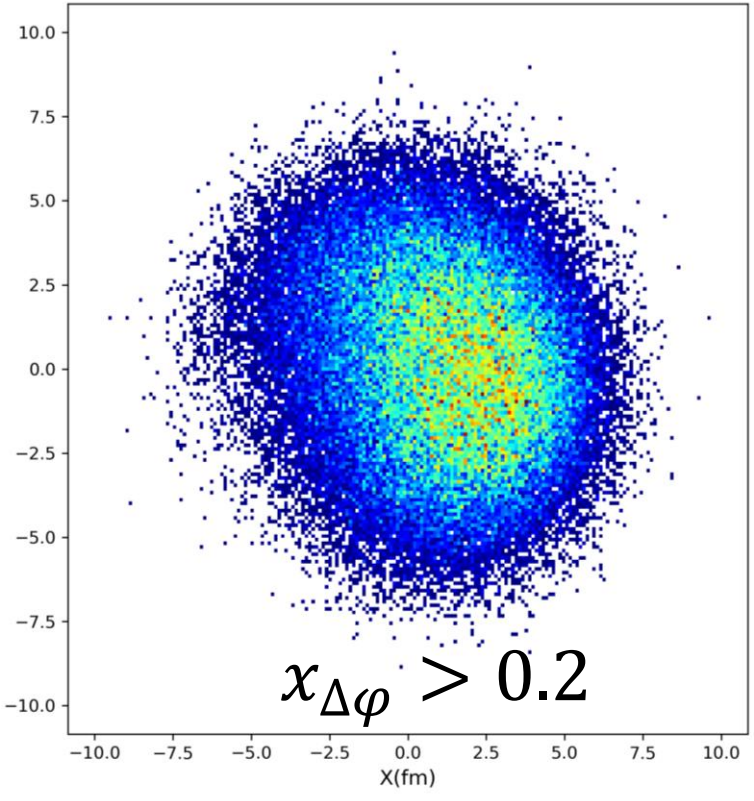
Jet localization with intra-jet asymmetry (γ-jet)



- Since the relative angle between jet and the event plane is random, we can use the jet axis as the coordinate axis y in the transverse plane.
- Better localization in multiple jets (Dijet) events?

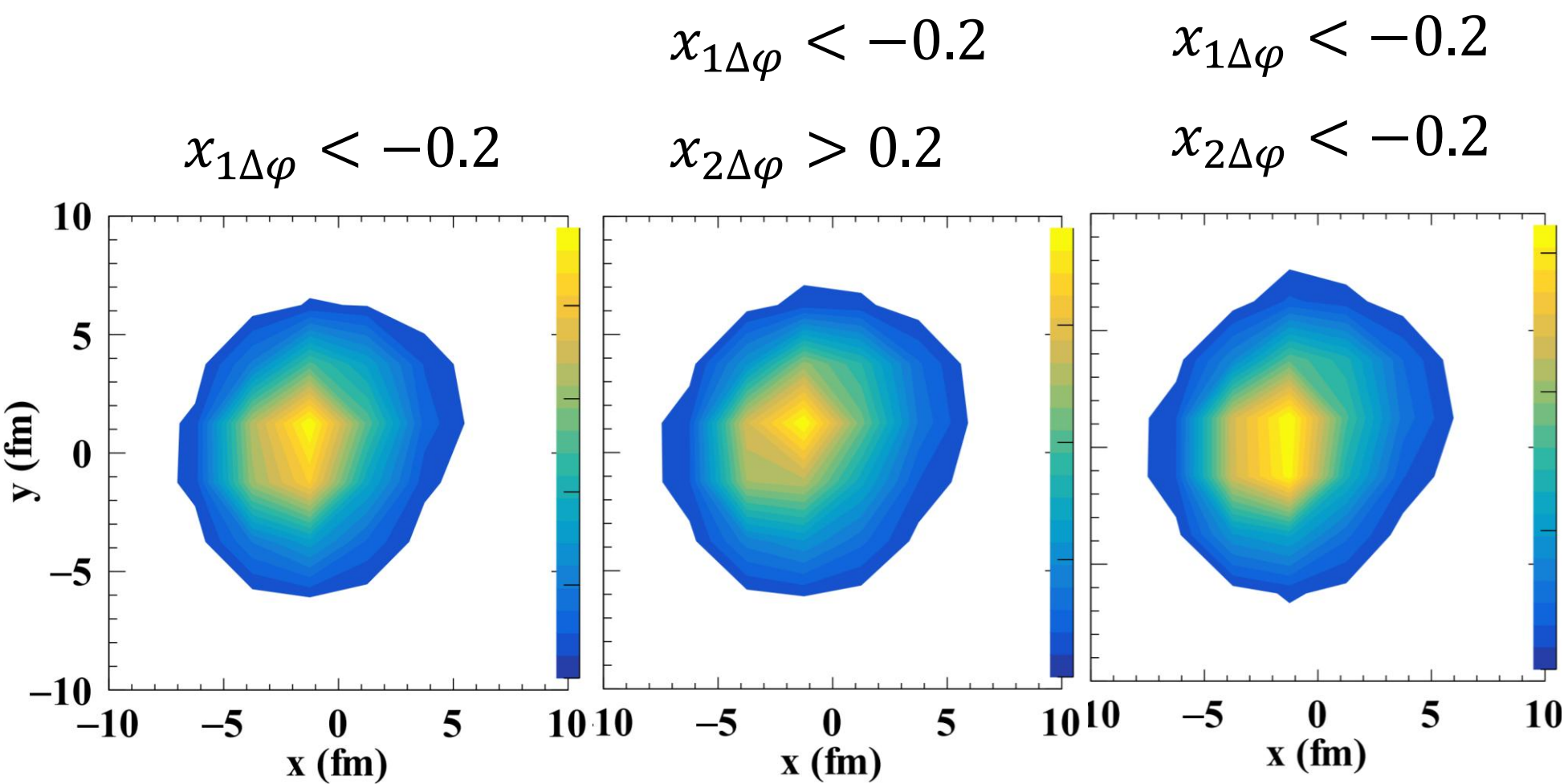


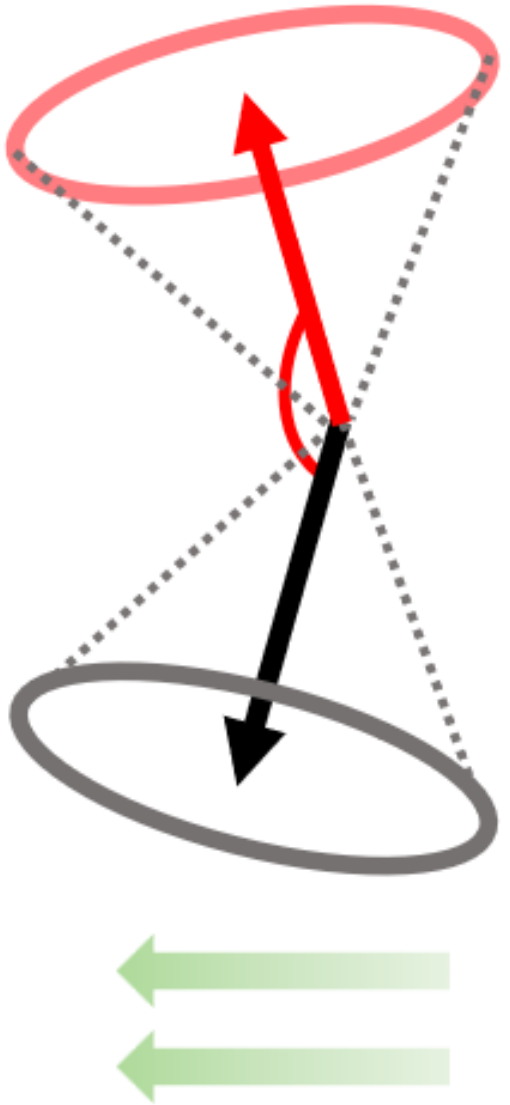




Jet localization with intra-jet asymmetry (Dijet)

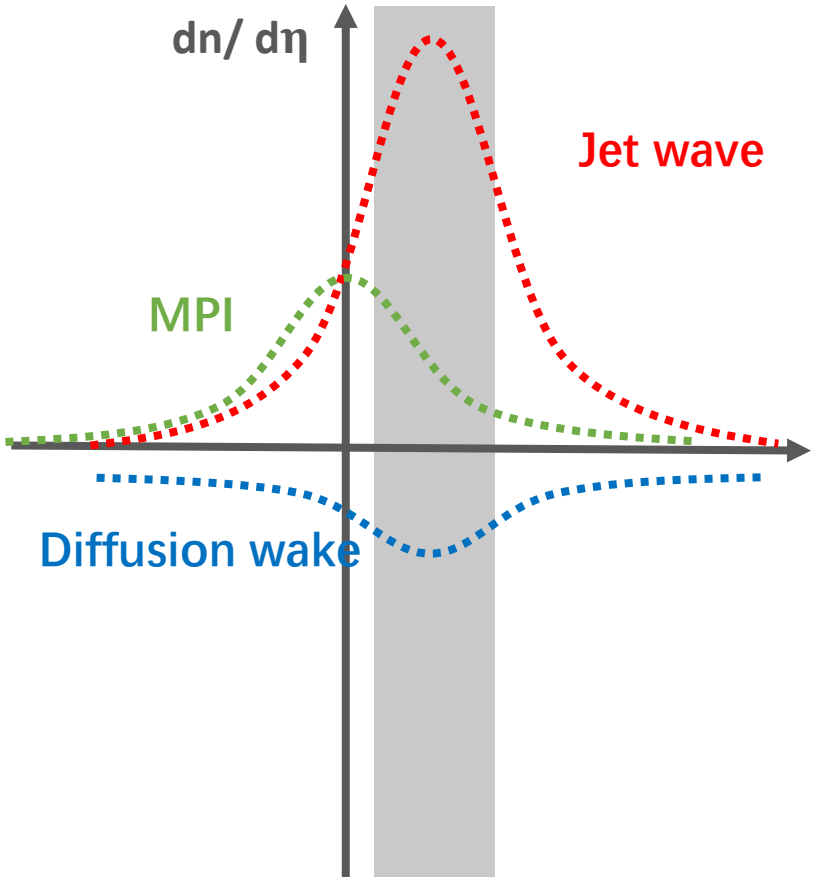
More jets, more information, better localization.
(Interplay with the jet-induced diffusion wake)

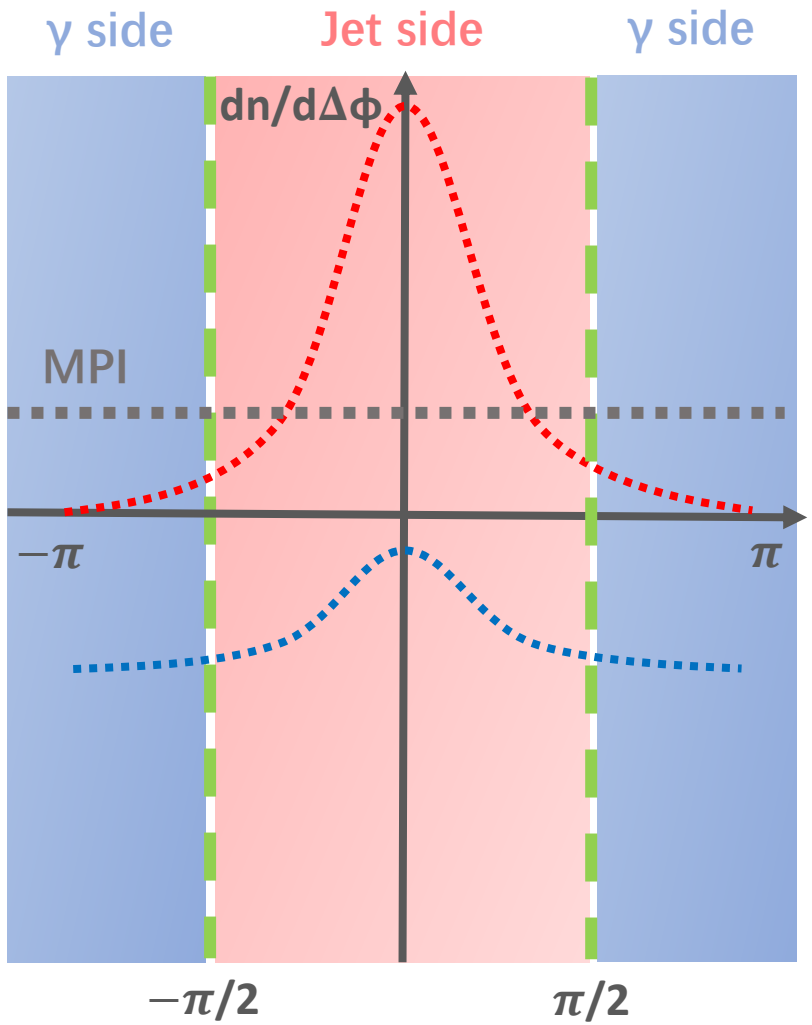


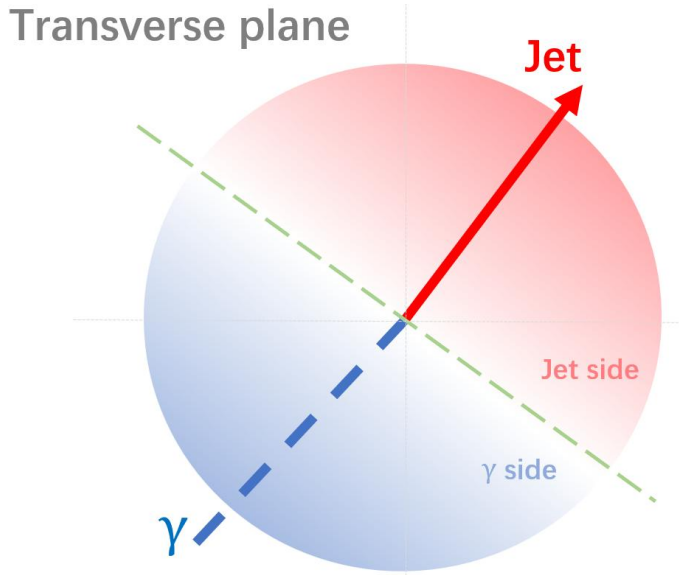


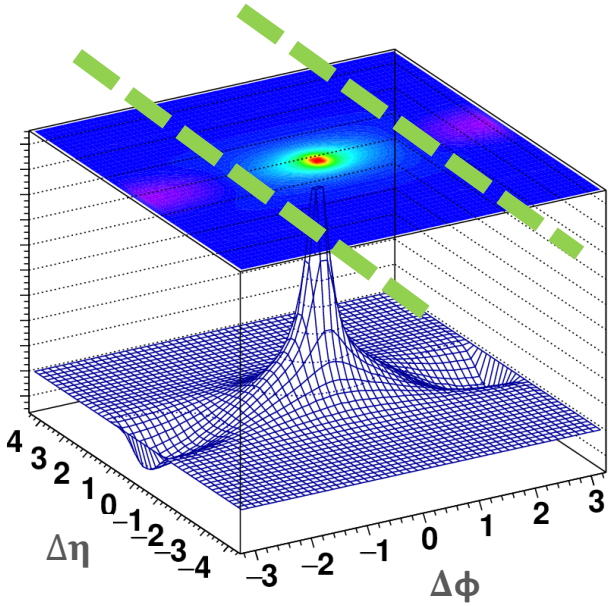
Searching for the diffusion wake

- A phase space cut in the transverse plane.
  (Jet hemisphere & γ hemisphere)

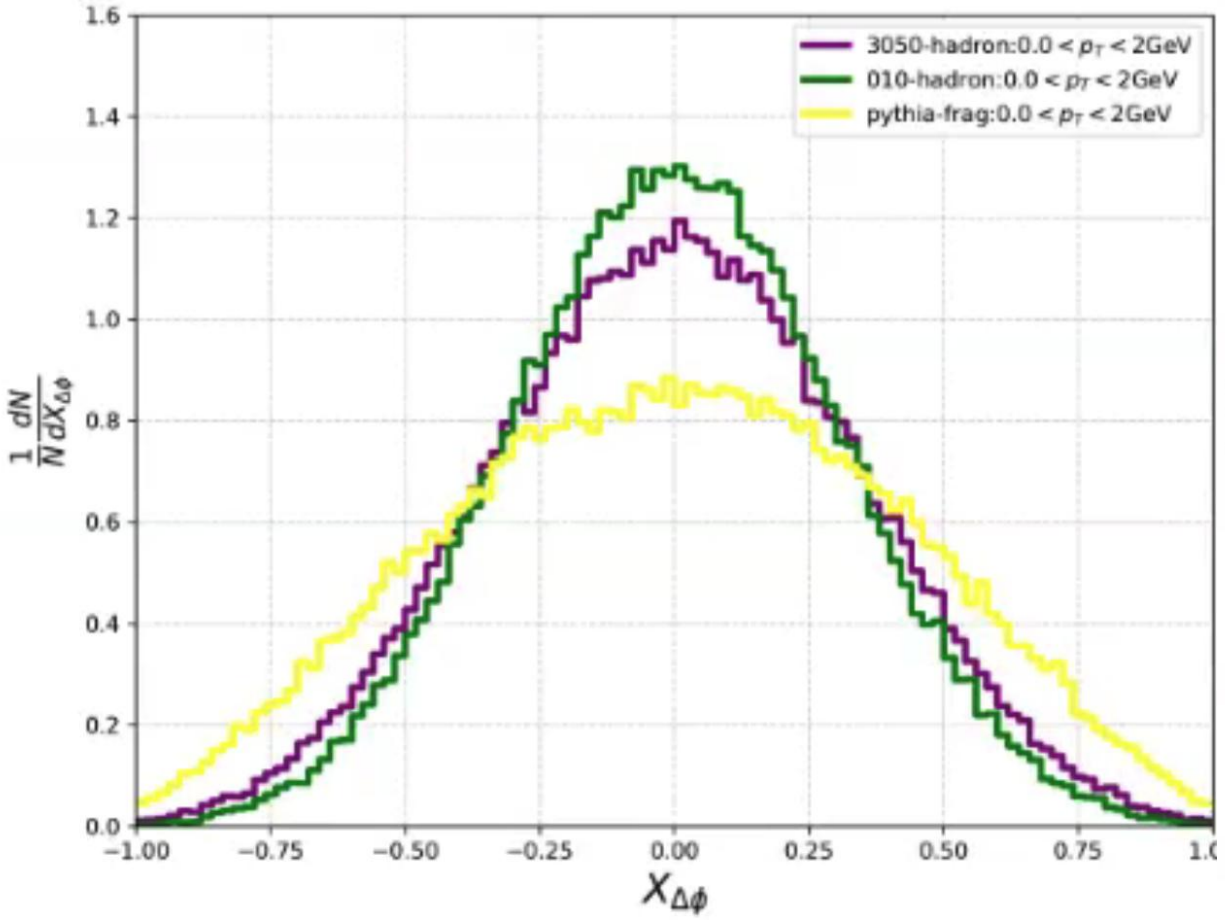


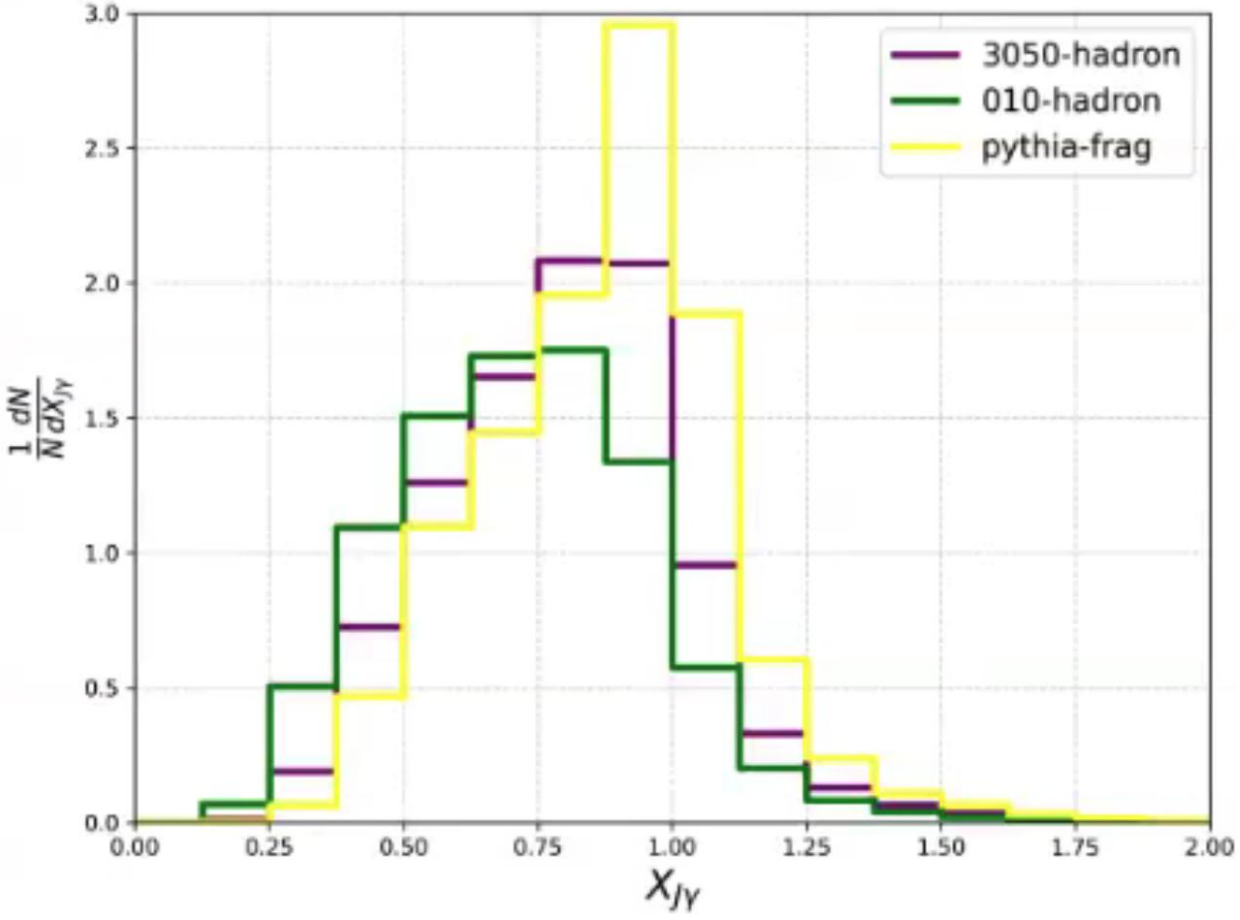




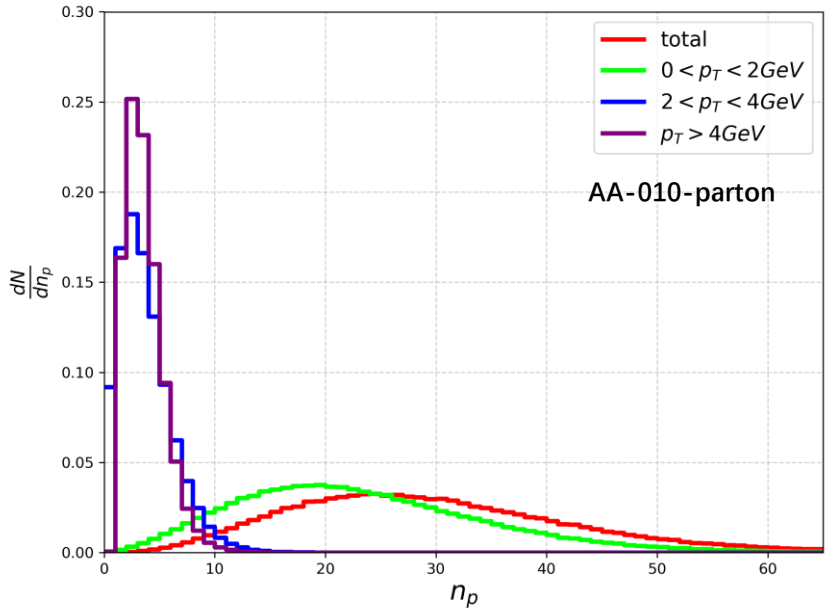


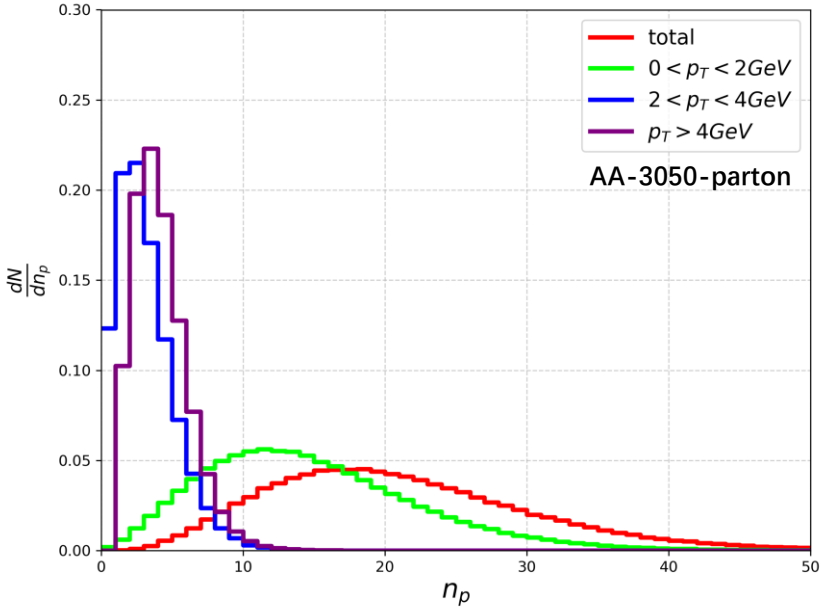
Jet induced medium response: a naive picture

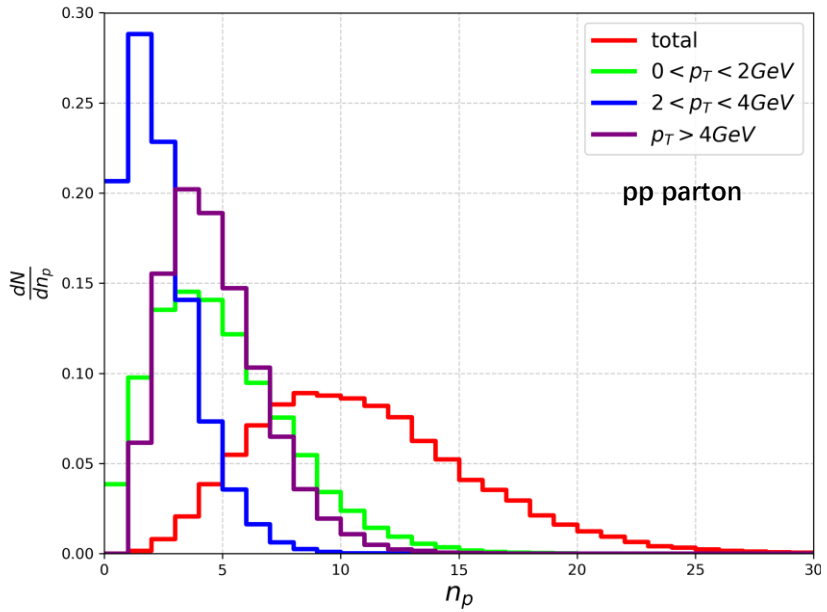


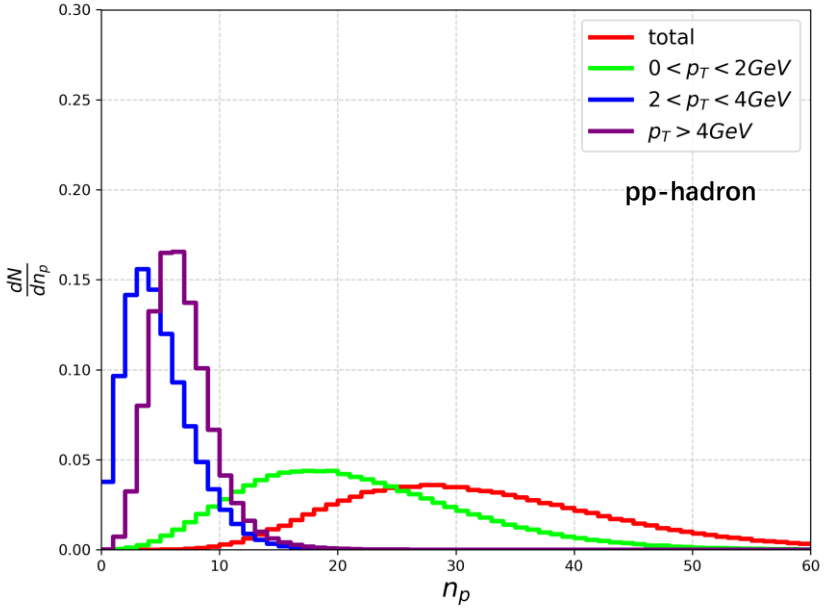


Jet multiplicity



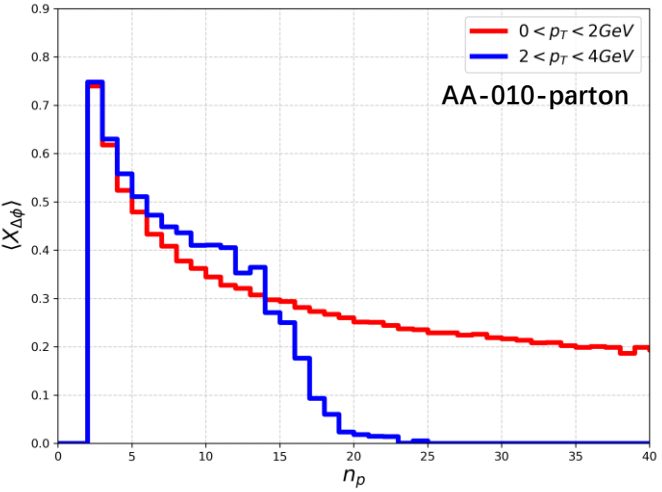


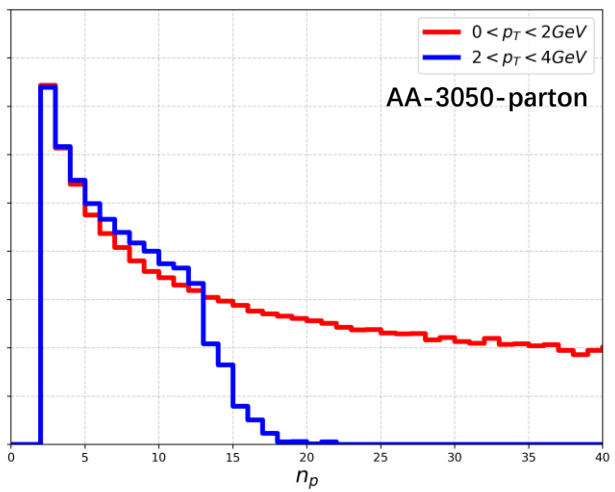


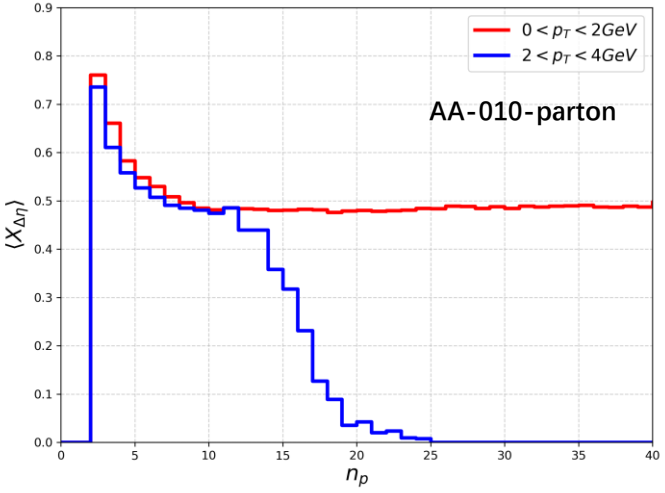


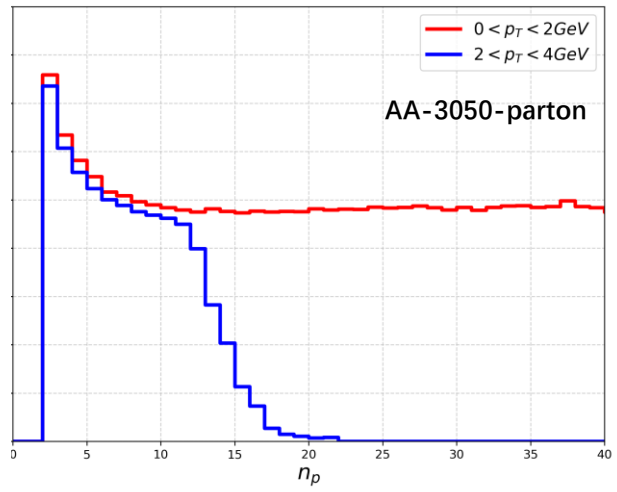
<A_phi>_dn_jet

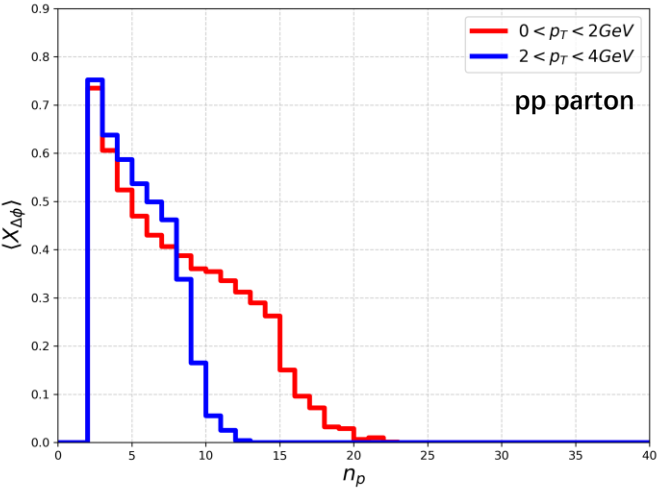
<A_eta>_dn_jet

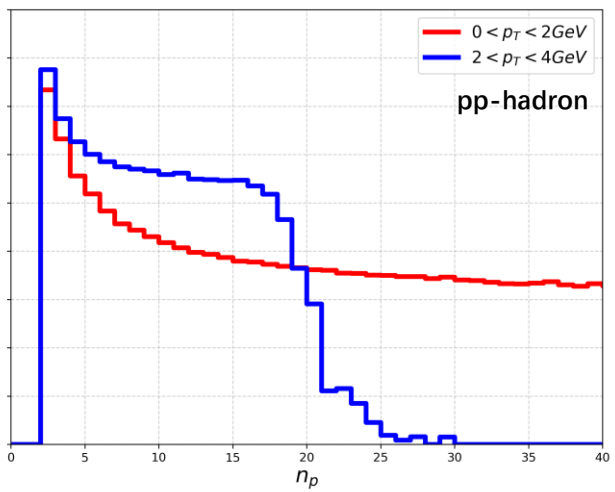


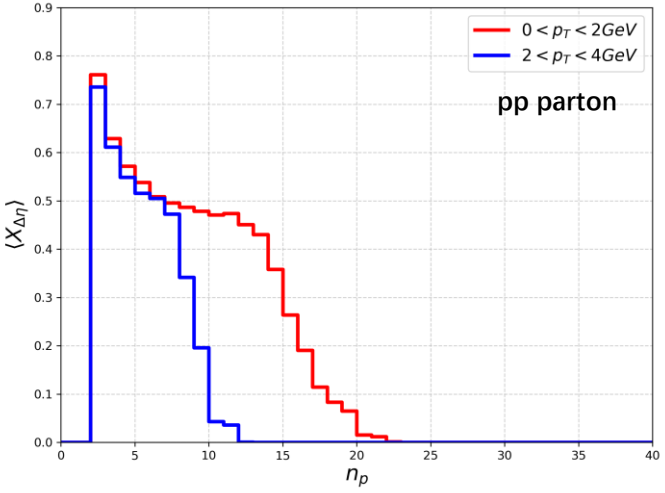


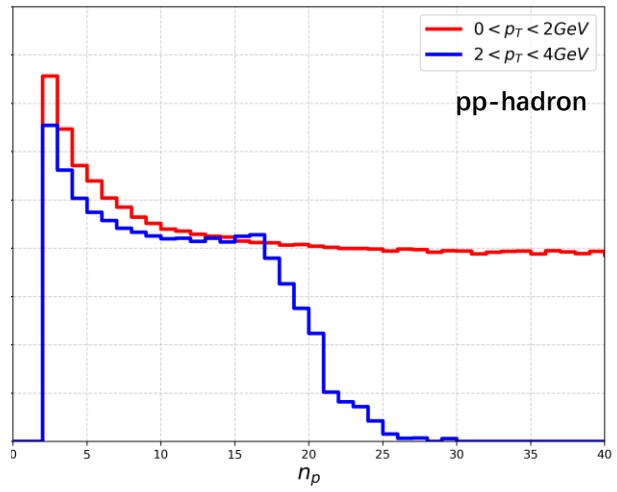


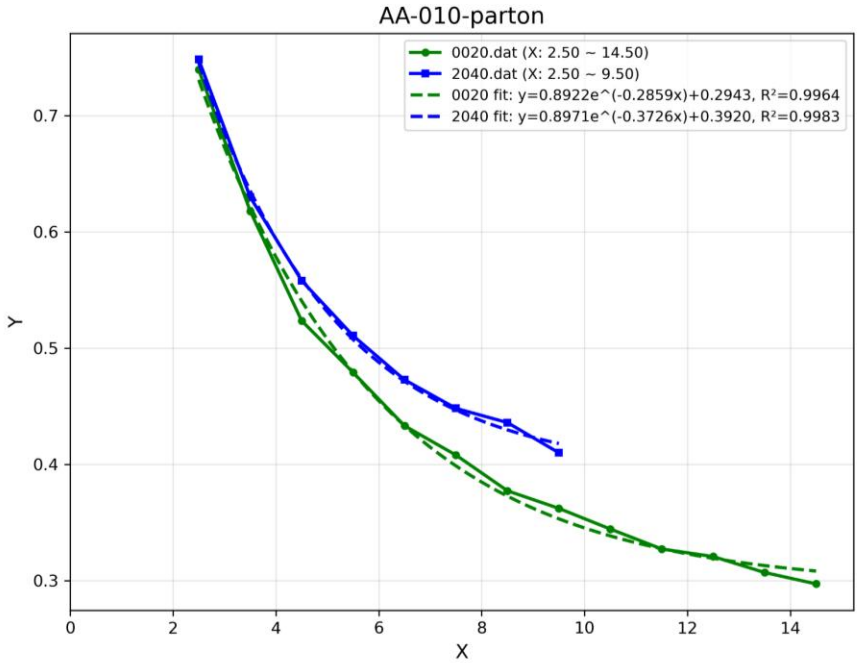


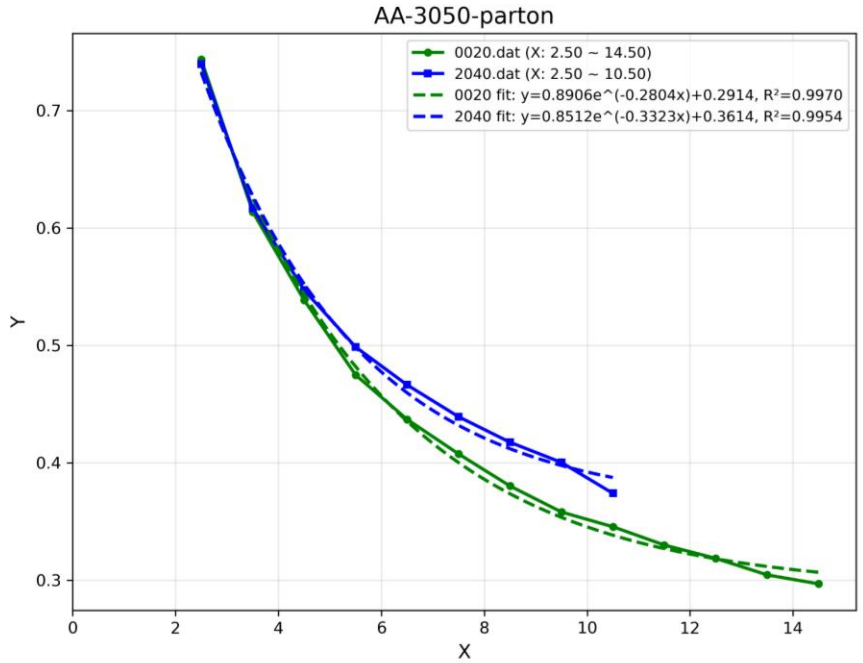


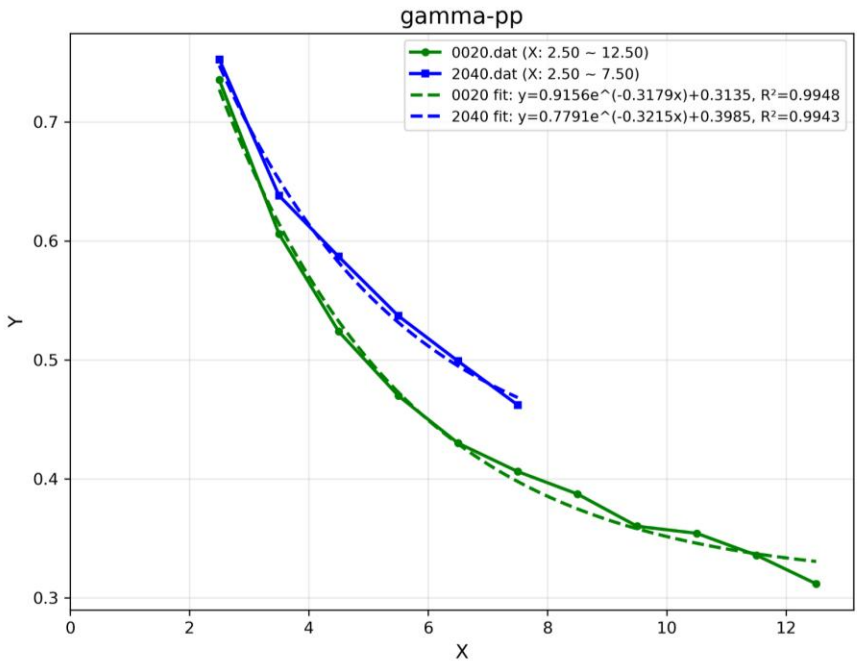


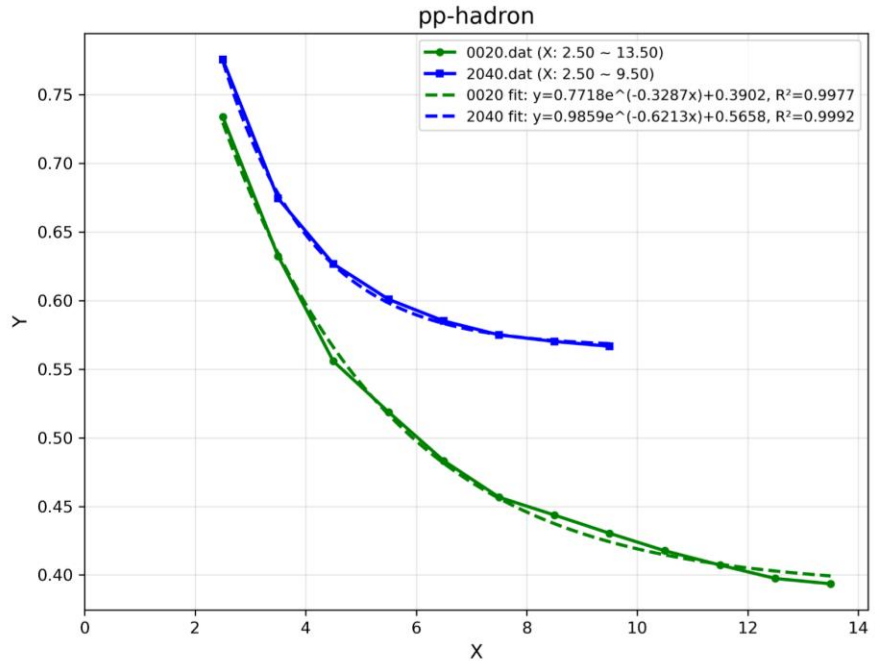





AA-010-parton
0020.dat (X: 2.50 ~ 14.50)
2040.dat (X: 2.50 ~ 9.50)
0020 fit: y=0.8922e^(-0.2859x)+0.2943, R²=0.9964
2040 fit: y=0.8971e^(-0.3726x)+0.3920, R²=0.9983
X
Y


AA-3050-parton
0020.dat (X: 2.50 ~ 14.50)
2040.dat (X: 2.50 ~ 10.50)
0020 fit: y=0.8906e^(-0.2804x)+0.2914, R²=0.9970
2040 fit: y=0.8512e^(-0.3323x)+0.3614, R²=0.9954
X
Y

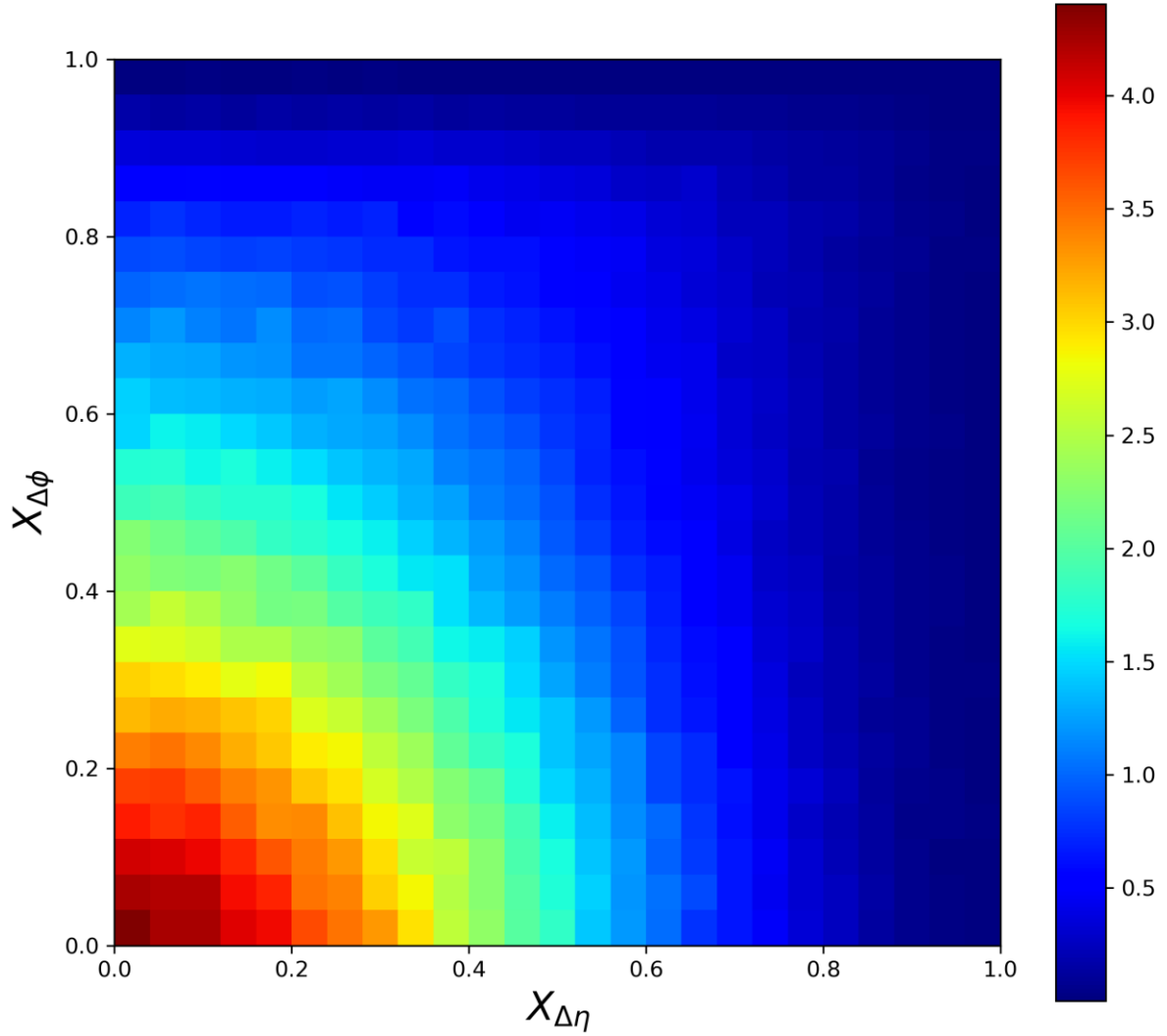

gamma-pp
0020.dat (X: 2.50 ~ 12.50)
2040.dat (X: 2.50 ~ 7.50)
0020 fit: y=0.9156e^(-0.3179x)+0.3135, R²=0.9948
2040 fit: y=0.7791e^(-0.3215x)+0.3985, R²=0.9943
X
Y


pp-hadron
0020.dat (X: 2.50 ~ 13.50)
2040.dat (X: 2.50 ~ 9.50)
0020 fit: y=0.7718e^(-0.3287x)+0.3902, R²=0.9977
2040 fit: y=0.9859e^(-0.6213x)+0.5658, R²=0.9992
X
Y

Intra-jet asymmetry in AA & pp collisions (γ-jet)

φ

- Intra-jet asymmetry (transverse .vs. longitudinal)



η

A Linear Boltzmann Transport (LBT) Model

Parton shower

Pythia Sherpa

Jet propagation

$$p_1 \cdot \partial f_1(x_1, p_1) = E_1 \left(C_{elastic} + C_{inelastic} \right)$$

- **Rescattering**
  Shower-thermal & recoil-thermal
- **Back reaction**
  Track the initial thermal parton

Fragmentation Recombination

LBT
Hard

Local medium information ε T $\boldsymbol{u}$

LBT Phys.Rev.C 109 (2024) 3, 034919

Hadronic observables

Initial profile

AMPT TRENTO

Medium evolution

$$\partial_\mu T^{\mu\nu} = 0$$

Cooper Frye

CLvisc
Soft

Intra-jet asymmetry increase in AA collisions (γ-jet)

- Large longitudinal asymmetry in pp .

- The longitudinal flow will push the particles inside the jet to the large rapidity range.